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ART. XIV.—*On the Color Correction of double Objectives;* by CHARLES S. HASTINGS.

I. *Review of attempted methods.*

IF we call the focal length of two thin lenses in contact P, one of the lenses being made of a material with indices of refraction n, and the other with indices indicated by n', we may write

$$\frac{1}{P}=\varphi=(n-1)\ A+(n'-1)\ B, \tag{1}$$

where A equals the sum of the curvatures of the two surfaces bounding one lens and B the corresponding sum for the other.

In order that this system may be achromatic it is necessary that P or φ should be invariable with n and n', or in other words that the equations

$$\frac{d\varphi}{dn}=0=A+\frac{dn'}{dn}\ B \tag{2}$$

$$A=-\frac{dn'}{dn}\ B \tag{3}$$

should be satisfied. Unfortunately this is in practice impossible, because at present no two varieties of glass are known in which $\frac{dn'}{dn}$ is constant. On the contrary, this coefficient is itself

a function of n and has an infinite number of values, all included in practical cases, however, within limits nearly approached. Thus, since the last equations cannot be satisfied for all values of n, the problem is reduced to finding that value of $\frac{dn'}{dn}$ which substituted in (3) will make the combination the most advantageous one.

The first efforts to find a solution of this problem were attended by one of the most brilliant discoveries in physical optics. Only in objectives of considerable size does the question become of great importance, and as Fraunhofer was the first to attempt such objectives, so he was first confronted with the problem. To solve it he performed an elaborate series of experiments on the optical properties of various glasses, during which he discovered the lines in the solar and certain stellar spectra universally known by his name. Moreover, as it was evident that the accepted value of $\frac{dn'}{dn}$ should depend upon the relative intensity of lights of different refrangibilities, he made a photometric determination of the brightness of the various parts of the solar spectrum. With data thus derived his theoretical method of determining the best value of the coefficient $\frac{dn'}{dn}$ was to deduce various values by observation, multiply each value so obtained by the relative brightness of the corresponding region of the spectrum, and divide the sum of these products by the sum of the numbers denoting the brightnesses. For example, if n_α, n_β, n_γ, etc., are the indices of refraction for the first medium corresponding to the Fraunhofer lines α, β, γ, etc., n'_α, n'_β, n'_γ, etc., the corresponding quantities for the second medium, and q_1, q_2, q_3, etc., are the relative quantities of light contained in the solar spectrum between the lines $\alpha\beta$, $\beta\gamma$, etc., then the accepted value of the coefficient is given by the equation:

$$\frac{dn'}{dn} = \frac{q_1 \frac{n'_\beta - n'_\alpha}{n_\beta - n_\alpha} + q_2 \frac{n'_\gamma - n'_\beta}{n_\gamma - n_\beta} + \text{etc.}}{q_1 + q_2 + \text{etc.}}.$$

Fraunhofer found, however, that for a combination of crown and flint glass this method always gives too large a value for $\frac{dn'}{dn}$, that is to say, that an objective so constructed would be notably under-corrected. Nor is it difficult to recognize that the theory is imperfect, for it implies that light of all refrangibilities is of value in the formation of the image exactly in

proportion to its intensity, whereas, in reality, light of the extremes of refrangibility instead of assisting in defining an image is absolutely harmful. Fraunhofer was driven, therefore, to a purely empirical determination of the quantity under discussion; and from his time to the present, the only way for an optician to determine the relative foci of the two components of an achromatic objective is by a laborious process of altering the curves and testing the result until the outstanding color about the image of a bright star is such as *experience* has shown is attended with good definition. A few of the more scientific opticians determine the coefficient by means of prisms instead of lenses, and thus, by a knowledge of the mathematical relations involved, save a great deal of manual labor. Still, even in the case where a pair of prisms combined to form a *diasporometer* is used, instead of a pair of lenses, the accepted value of the coefficient depends upon an exercise of the judgment alone, and hence this process yields no unambiguous solution.

II. *A Theoretical Solution.*

In order to investigate the best theoretical value for the coefficient $\frac{dn'}{dn}$, we may begin by expressing n' either directly or indirectly as a function of n. The most naturally suggested course is to express each as a function of the wave-length of light according to Cauchy's well known formula; but not only is the labor of computing the constants for the necessary three terms of such a formula great, but the accuracy of the expressions thus obtained is very inconsiderable. In another article,* however, I have shown that n' may be expressed, for all cases of practical importance, as a function of n by a simple trinomial of the second degree so that the residuals are smaller than the errors of observation except in cases where very extraordinary accuracy is attained.

We have thus:

$$n' = \alpha + \beta n + \gamma n^2 ;$$

and the equations above become

$$\frac{1}{P} = \varphi = (n-1)\ A + (\alpha - 1 + \beta n + \gamma n^2)\ B \qquad (1')$$

$$\frac{d\varphi}{dn} = 0 = A + (\beta + 2\gamma n)\ B \qquad (2')$$

$$A = -B\ (\beta + 2\gamma n). \qquad (3')$$

The problem is to determine the particular value of n which can be most advantageously substituted in the last equation.

* On Triple Objectives with Complete Color Correction. This Journal, vol. xviii, p. 429, 1879.

This value will be designated as n_0 and the corresponding focal distance as P_0.

To accomplish the solution we must first find a criterion of excellence in an objective. This we may easily do, after defining the sense in which we here use certain terms, as follows:—

Light, for the purpose of this investigation, is defined as that form of radiant energy which affects the retina; its quantity is measured, not by the value of the energy, but by the physiological effect which it is capable of producing.

The *intensity of light of refrangibility* n is measured by the quantity of light contained between the refrangibilities n and $n+dn$ divided by dn. Thus, if q_n equals the quantity of light so defined and ι_n its intensity, then

$$q_n = \iota_n dn.$$

In what follows we shall consider only such light as is given out by a very hot solid body. This light is composite and contains light of all refrangibilities from a little less than that of the Fraunhofer line A to, practically, a little more than that of the line H. We let n_r and n_v represent these limits of refrangibility. Then, if Q is the total amount of light falling upon a given area, e. g. upon an objective, we have evidently

$$Q = \Sigma q = \int_{n_r}^{n_v} \iota \, dn.$$

In this expression ι is an unknown function of n, but we know enough of the properties of this function for the present purpose.

A perfect objective would concentrate *all* the light incident upon it from a distant point in its axis to a very small circular area in the focal plane, which area would be constant for all telescopes of the same angular aperture. The most perfect attainable objective then would be that which concentrates the greatest attainable amount of light within this area. To investigate the conditions which must be satisfied to this end we must determine the amount of light falling within a small circular area σ at P_0, the radius of which we will set as $a \operatorname{tg} \frac{1}{2}\alpha$, where α is the angular aperture of the objective. It is evident that all the light of such refrangibilities as substituted in (1′) would yield values of P contained between P_0-a and P_0+a would fall within the area σ. These limiting refrangibilities shall be denoted by n_{-a} and n_{+a}. Only a portion of the light of refrangibilities less than n_{-a} and greater than n_{+a}, however, falls upon this area, the amount for light for the refrangibility n being clearly,

$$q_n \frac{a^2}{(P_0-P_n)^2};$$

hence the total quantity of light falling upon σ would be equal to the sum of three integrals, the first taken from the extreme red up to n_{-a}, the second from n_{-a} up to n_{+a}, and the third from this last limit up to the extreme violet; that is, if q be this quantity,

$$q=a^2\int_{n_r}^{n_{-a}}\frac{\iota_n dn}{(P_0-P_n)^2}+\int_{n_{-a}}^{n_{+a}}\iota_n dn+a^2\int_{n_{+a}}^{n_v}\frac{\iota_n dn}{(P_0-P_n)^2}.$$

To find the value of n_0 which will render the last expression a maximum, it is necessary to find the first derivative of the function with respect to n_0 and set it equal to zero. Remembering that $\frac{dP_0}{dn_0}=0$, we see that P_n, n_{-a} and n_{+a} are the only quantities dependent upon n_0, hence we obtain by differentiation under the signs of integration,

$$\frac{dq}{dn_0}=0=-2a^2\int_{n_r}^{n_{-a}}\frac{\iota_n dn}{(P_0-P_n)^3}\frac{dP_n}{dn_0}+a^2\frac{\iota_{n_{-a}}}{(P_0-P_{n_{-a}})^2}$$

$$+\iota_{n_{+a}}-\iota_{n_{-a}}-2a^2\int_{n_{+a}}^{n_v}\frac{\iota_n dn}{(P_0-P_n)^3}\frac{dP_n}{dn_0}-a^2\frac{\iota_{n_{+a}}}{(P-P_{n_{+a}})^2}.$$

But from the definition of the quantities n_{-a} and n_{+a} we have

$$(P_0-P_{n_{-a}})^2=(P_0-P_{n_{+a}})^2=a^2.$$

Hence the value of $\frac{dq}{dn_0}$ reduces to minus the product of $2a^2$ into the sum of two definite integrals, and the problem becomes simply the determination of the value of n_0 which will cause this sum to vanish, or, since $\frac{dP_n}{dn_0}\frac{1}{(P_0-P_n)^3}$ must have opposite signs in the two integrals because $\frac{dP_0}{dn_0}=0$, that value which will make the two integrals equal. If both ι_n and P_n were symmetrical with respect to some one value of n, that value would evidently answer the condition; otherwise it is necessary to know the function ι_n.

It would be easy to find a transcendental function which would express empirically the photometric observations of Fraunhofer, or the more recent and elaborate ones of Vierordt, but a simple consideration of the physical limitations of the problem will enable us to dispense with this operation.

Hitherto we have made no restrictions as to the value of σ. Let us now suppose that σ is so small that it may be regarded as the image of a star, then a is small and, since $\frac{dP_0}{dn_0}=0$, P_n may

be regarded as symmetrical with respect to n_0 for values not differing largely from P_0. Again, for white light, ϵ_n is shown by the photometric observations above named to have a single maximum corresponding to a certain value of n which we will designate as n_1, and consequently may be regarded as a symmetrical function of n in the region of this maximum. Finally $\frac{dP_n}{dn_0}$ is never large in practical cases between the limits n_r and n_r while $P_0 - P_n$ increases continuously in numerical value toward these limits. If then we set $n_0 = n_1$ the two definite integrals become sensibly equal and q is a maximum.

The value n_1 corresponds to light of a refrangibility greater than that of the Fraunhofer line D and less than that of E, nearer, however, to the former. The only prominent Fraunhofer line readily seen with a crown glass prism of moderate dimensions in this region is that of wave length 5614. This I will assume as defining n_0 and consequently the ratio of A to B in (3′).

In all substances practically useful in telescope-making, γ of (2′) is positive, therefore P_0 is a minimum.

The reasoning given above is evidently applicable to all forms of radiation transmitted by the lens system if appropriate definitions for q and ϵ are given and ϵ possesses a single maximal value. For instance, in the case of radiant energy, pure and simple, n_0 should equal n_r nearly (lenses of glass); and for a photographic objective where silver salts are to be acted upon n_0 should be nearly equal to n_G.

It will be observed that the term color and all considerations relating to color have been entirely omitted from the discussion. This is what we might have anticipated as a necessary feature from the remarks on page 170.

One consequence of the solution above developed may be here noted, viz: the focal plane is defined by P_0 and not by two like values of P_n greater than this minimum. This is contrary to the doctrine of some writers but in accordance with critical experiments.*

III. *Method of applying the results to the practical construction of an objective.*

The solution obtained cannot be directly applied as a guide in the construction of an objective, for P is by no means the simple function of n, A and B as implied in equation (1′) when real lenses are in question. Even if we confine our attention to central rays and employ the exact formulas of Gauss, the process becomes so involved that we would naturally seek an

* See paper cited above, pp. 434–435.

easier, even if indirect, method; to a still greater degree if we wish to consider the far more important marginal rays.

There are several evident methods of finding indirectly the constants of the objective, but the most practicable one has seemed to me the following:

We have as data α, β and γ in the formula

$$n' = \alpha + \beta n + \gamma n^2 ;$$

also F, the required focal length of the objective. Then set

$$\frac{1}{P_0} = \frac{1}{F} = (n_{5614} - 1)\ A + (n'_{5614} - 1)\ B$$

$$A = -B\ (\beta + 2\gamma n_{5614}).$$

These last two equations yield the values of A and B. In the general equation (1′) substitute these values of A, B, α, β, γ with some known value of n other than n_{5614}, e. g., I have generally used the value n_C. Its solution will give the value of the focal length for light of the refrangibility C. Let this value of P be substituted in turn in equation (1′) and solve with respect to n. We shall thus obtain two values of n, one of which is n_C and the other a value greater than n_{5614} which we may call n_c, and if we substitute this in the equation connecting n and n' we shall be able to derive the corresponding value n'_c. This is all that the consideration of infinitely thin lenses can do for us, but from it we have found that the rays of refrangibility denoted by C and c should have a common focus, and we have also the values

n_c	n'_c
n_{5614}	n'_{5614}
n_e	n'_e

Having given, the thickness of the lenses and the distance between them, and having assumed radii proper to correct spherical aberration, we calculate the courses of three marginal rays of refrangibilities defined above, and of one central ray of refrangibility 5614. By successi e trials and modifications of three of the radii we can meet the three conditions, that the marginal and central rays 5614 unite in a point on the axis, that this point is at a distance F from the second principal point of the system, and that the marginal rays C and c unite at another point on the axis. The remaining arbitrary constants, viz: the thicknesses, distance and fourth radius, may be utilized for the purpose of satisfying other conditions; but the consideration of such conditions is at present foreign to our purpose.

IV. *Practical tests of the value of the foregoing theory.*

There are two evident methods for determining the value of the results which we have obtained; one is to construct a telescope according to the principles developed in the theory and study its performance, and the other is to find how the practice of the most approved makers agrees with that as founded upon the theory. Both of these tests I have applied with thoroughness and will here give the results in the order named.

Three object glasses, involving the use of six varieties of glass, have been constructed according to the principles developed above. The first was of 4·1 inches aperture and 53 inches focal length, with the flint in advance of the crown. The materials of which this objective are made are the flint glass of Feil, No. 1237, and the crown glass of the same maker, No. 1219.* The focal length was purposely made small so as to yield the severer test.

The second objective has a clear aperture of $6\frac{1}{4}$ inches and a focal length of 91 inches. The crown lens is in advance and the curves are such as satisfy, for a first approximation, the conditions proposed by Sir John Herschel. This form, though ordinarily known as Herschel's, cannot be said to differ from that chosen by Fraunhofer at a date earlier than that of the publication of Herschel's paper.

The third experiment was tried at the instigation of my friend Mr. C. H. Rockwell, who bore the expense of the fine disks employed. These were ordered from Feil at Paris, and were of exceptional thickness in order to allow greater latitude in the selection of radii. The objective has a clear aperture of 9·4 inches and a focal length of 141 inches. It has undergone a critical investigation at the observatory of Cincinnati. As it possesses a number of novel features other than that of its color correction, I may give a complete description of it at another time.

All of these lenses were finished strictly in accordance with the theory developed in this paper, that is, the curves were ground very exactly according to the values yielded by calculation and the objective *finished* before testing. An extremely delicate spherometer was employed to determine the radii. As all the objectives are of the highest excellence, the usefulness of the theory may be regarded as demonstrated.

For the second test proposed, we possess the results of the studies of two distinguished spectroscopists on the character of the color correction of several large telescopes. To these I can add two more.

* The optical properties of these glasses as well as those of the $6\frac{1}{4}$ inch objective are given in a paper entitled, On the influence of Temperature on the Optical Constants of Glass. This Jour., vol. xv, pp. 269–275, 1878.

Professor Vogel, in the Monatsbericht d. k. Preuss. Akademie d. Wissenschaften for April, 1880, has described three large telescopes in respect to their color correction, one by Schröder of 298^{mm} aperture, another by Grubb of 207^{mm} aperture, and a third by Fraunhofer of 243^{mm} aperture, as determined by observing a stellar image spectroscopically. A fourth objective by Steinheil of 135^{mm}, less completely investigated, is of little importance to us here on account of its smaller size. The method was to determine the various lengths of the telescope when a stellar image, observed through the eye-piece armed with a prism, was caused to exhibit the greatest contractions at recorded intervals in its spectrum.

Professor Young, in this Journal for June, 1880, gives the results of his measurements on two telescopes by the Clarks, each of nearly nine and a half inches aperture. The method employed was analogous to that of Vogel except that a very powerful spectroscope was used and the limb of the sun taken instead of a star. By this means the focal planes for various wave lengths of light were determined by the position of the slit plate of the spectroscope.

In the summer of 1879 I determined, by the method last described, the color characteristics of Mr. Edgecomb's telescope at Hartford, Conn., a 9·4 inch objective by the Clarks, and, with Professor Van Vleck's assistance, those of the 12-inch Clark at the Wesleyan University.

To compare these various successful practical solutions with that given by the theory embodied in this paper, I found by interpolation, using the first two terms of Cauchy's formula, the wave lengths corresponding to the various values of n_e, that is, those wave lengths which should have, according to theory, their focal point coincident with light defined by the Fraunhofer line C. They are for

	W. L.
Crown glass 1219	500·4
" " of $6\frac{1}{4}$ in.	499·5
" " of 9·4 in.	498·6
Flint glass 1237	500·7
" " of $6\frac{1}{4}$ in.	499·7
" " of 9·4 in.	498·9
Mean,	499·6

The corresponding values as derived by measurement from various telescopes are as follows:—

W. L.	Makers.	Authority.	Remarks.
530	Fraunhofer.	Vogel.	
465	Schröder.	"	
494	Grubb.	"	
490	Clark.	Young.	Princeton telescope.
522	"	"	Dartmouth.
495	"	Hastings.	Edgecomb's.
497	"	"	Wesleyan Univ.
499·0	Mean.		

The close agreement of these means may be taken as a decisive proof of the correctness of the theory.

The almost identical values of the wave length of light which should unite at the focus with the light C for six varieties of glass suggests another method of applying the results of the theory in practice, which is a very simple one. The nearest prominent Fraunhofer line to this wave length, that is, the nearest one which can be readily measured in a spectrum produced by a small crown glass prism, is W. L. 500·5. Hence, in practice, determine the indices of refraction for the lines C, W. L. 561·4 and W. L. 500·5 in both materials to be used; calculate the curves of the objective so that the spherical aberration for ray 561·4 shall vanish while marginal rays C and 500·5 have a common focal point. This method, though simple and direct, is without doubt sufficiently correct for all telescopes of moderate apertures and all varieties of glass hitherto used in their construction.

Johns Hopkins University, Jan., 1882.

ART. XV.—*To Cut a Millimeter Screw;* by CHARLES K. WEAD.

THE increasing attention paid to the metric system renders it more and more desirable to put the relations between this and the English system of weights and measures in as simple a light as possible. If a screw is to be cut on an ordinary lathe with its pitch a convenient number of teeth to the millimeter, centimeter or meter, the change-wheels are not adapted to the purpose. The only reference I have ever found to the subject is in Chambers' Encyclopedia, article "Wheelwork," where the problem is given to compute the gears needed to cut a screw of 200 threads to one meter, on a lathe whose feed-screw has four threads to the inch; by continued fractions the number of teeth, beginning with the spindle, is found to be 50, 48, 89, 73; i. e., if x=number of threads to 1 inch,

$x=\frac{50\times89}{48\times73}\times4=5{\cdot}08$, or, in 1 meter are $5{\cdot}08\times39{\cdot}37=200$ threads. This requires two gears with a prime number of teeth.

A simpler method than this I suggested four years ago to Messrs. Buff & Berger, of Boston, and by it they cut me some very satisfactory screws with 1 thread to the millimeter, using their new lathe with two dead centers; as it was new to them, and to all my friends familiar with mechanical work to whom I have spoken of it, I venture to publish it though it seems too simple to have escaped previous notice.

The method is based on the fact that 1 inch equals very nearly 25·4 millimeters; it would equal it exactly—

If one meter equals	39·37008	inches.
Clarke's value	"	39·37043	"
Kater's	"	"	39·37079	"

This "mechanical" meter differs from the best determination yet made, Clarke's, by no more than that differs from the next best one, viz: $\frac{1}{10000}$ part, though in the opposite direction. The form in which the direction was given to Buff & Berger was, "gear the lathe so as to cut a screw with twenty threads to the inch, with a gear of 100 teeth on the feed-screw; replace the 100 by 127 $\left(=\frac{254}{2}\right)$, and the pitch will be 1 millimeter, the theoretical error being much less than the mechanical error of cutting." Thus, on the lathe above referred to, $x=\frac{127}{20}\times4=25{\cdot}4$ to the inch, or 1 to the millimeter; again, $x=\frac{127}{100}\times4\div25{\cdot}4=\frac{1}{5}$—i. e. 1 thread to 5 millimeters.

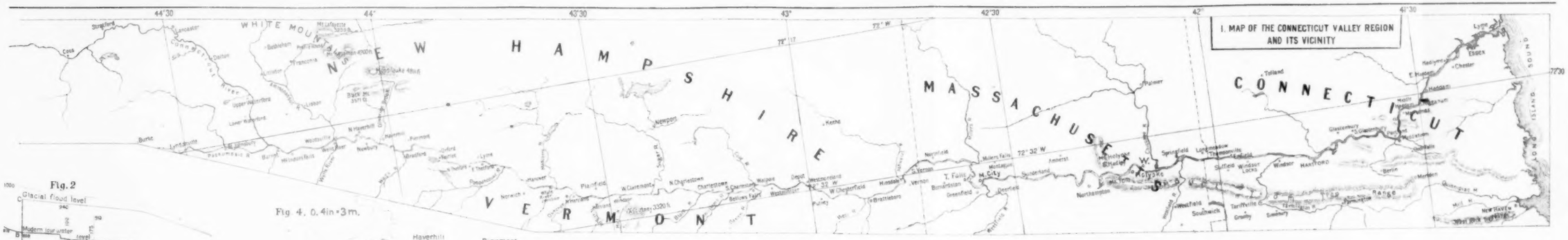
On small lathes it may often be necessary to put the 127 gear on the arm because the screw and spindle are too near together, and perhaps to get a longer arm than usual; but neither this nor the calculation for any whole number of threads to the millimeter, centimeter, or decimeter will present any great difficulty to any one familiar with the principle.

Physical Laboratory, University of Michigan, Dec. 15, 1881.

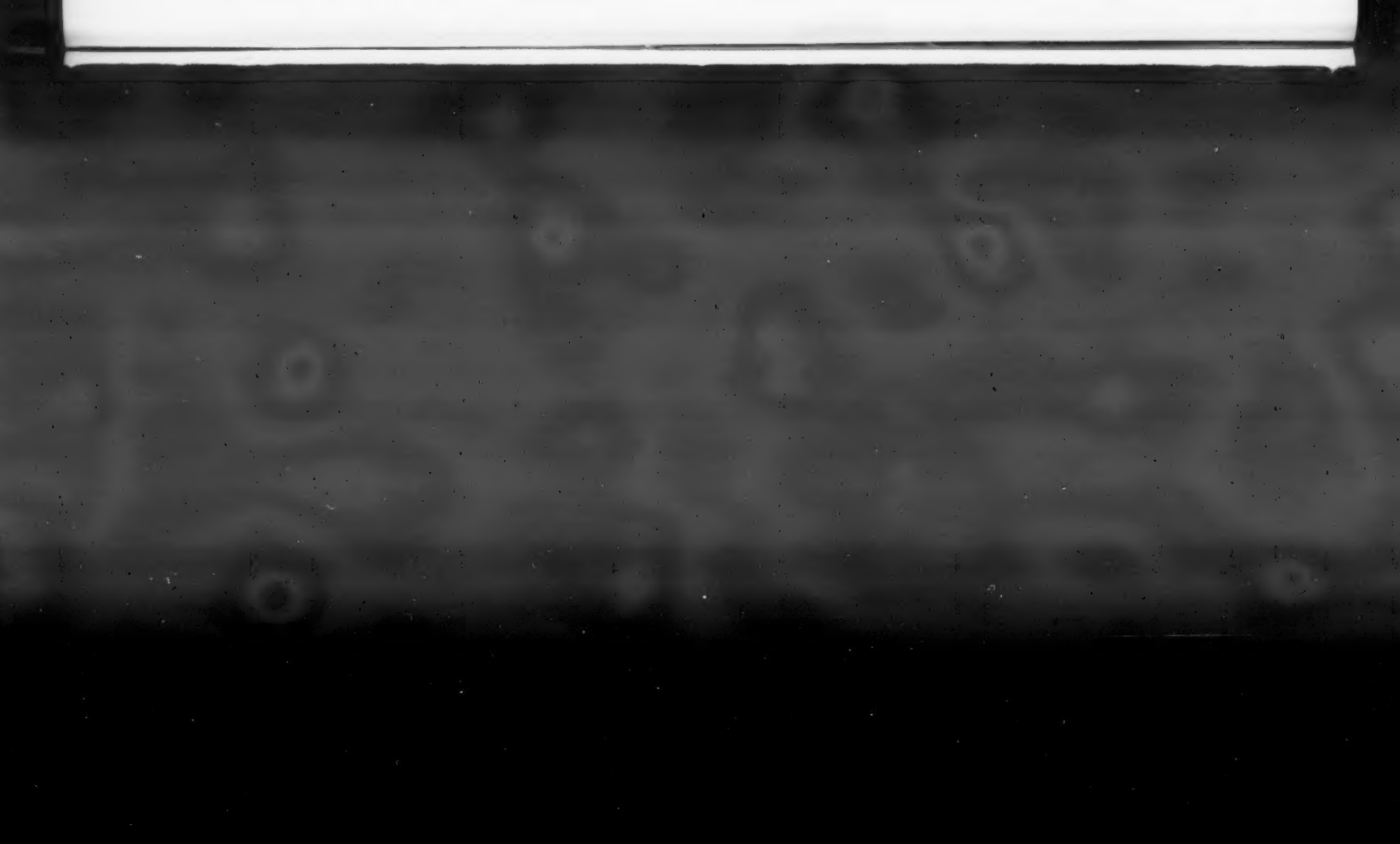
ART. XVI.—*On the Gold-bearing Rocks of the Province of Minas Geraes, Brazil*; by ORVILLE A. DERBY.

THE rock series of Minas Geraes, which have heretofore been recognized as auriferous, are the gneisses and mica schists of the crystalline group, and the quartzites, unctuous schists, and iron ores (itabirites), of the less highly metamorphosed group of rocks succeeding the crystalline series. To these may be added a second group of quartzites lying unconformably on the second metamorphic series. In all these rocks the gold is in, or in the immediate vicinity of, veins of quartz, generally if not always accompanied by pyrites, cutting the beds or accompanying the bedding, or in vein-like lines of a peculiar clay or iron ore. In a recent trip down the Rio das Velhas I noticed that long after having passed the region in which rocks generally recognized as auriferous were exposed on the river bank, the sand and gravel deposits of the bed are apparently as rich in gold as are those within that region. At the same time trial washings at the mouths of the rivers Parauna and Pardo, tributaries which at a short distance from the main river issue from the auriferous series about Diamantina, and might therefore be supposed to be richer in transported gold, proved that the sands of these streams are much poorer than those of the main river, and go to show that gold even in rapid flowing rivers is transported a much less distance than is generally imagined. An examination of the numerous quartz veins which traverse a series of inclined beds of clay slates, limestones and sandstones, quite distinct from the metamorphic series, revealed the fact that many of them carry pyrites and gold. This series has not, so far as I am aware, been recognized as auriferous. This series is of uncertain age, but is probably Paleozoic.

Another peculiar formation has been extensively worked at the city of Saõ Joaõ Delrei. The rock here is an ancient conglomerate containing rolled pebbles of itacolumite, unctuous schists, etc., and, except in its conglomerate character, bears so close a resemblance to the upper quartzite series above mentioned that it is difficult to doubt its identity. The gold is apparently in its secondary deposit in this rock. I have elsewhere attempted to show that at Grão Mogol, in the northern part of the province, a similar conglomerate of the same series is a secondary deposit of the diamond, and have now to add to this list of diamantiferous and, to a small extent, auriferous conglomerates, of the upper quartzite series, the heavy beds of Curralinho and Bom Successo to the east, and of Guinda and Sopa to the west of Diamantina. In the west of the province a newer conglomerate appears to have furnished the diamonds of the Jezuetaby and Abacté washings.



2. SECTION OF THE CONNECTICUT RIVER DURING THE FLOOD FROM THE MELTING GLACIER



ART. XVII.—*The Flood of the Connecticut River Valley from the melting of the Quaternary Glacier;* by J. D. DANA. With Plate II.

[Continued from page 97.]

4. *Dimensions and velocity of the flooded Connecticut.*

IN the preceding pages it has been shown that during the era of the melting of the glacier the Connecticut River and its tributaries participated together in the rising flood and in the work of transportation and deposition; that the tributaries brought in the chief part of the materials for the terrace-formation; and that the main stream left its best registerings of high-water mark in the deposits about or near their mouths. When the flood was at its height, the Connecticut was one continuous stream, hurrying seaward, as it is, though in a more moderate way, during a modern flood.

We may now seek to determine approximately the dimensions and velocity of the river when at maximum flood, taking up the several points in the following order:—(1) the height of the waters; (2) the mean depth; (3) the mean width; (4) the mean slope; (5) the velocity. As to the height along the valley, the facts are obtainable with a near approach to accuracy from the height of the normal upper terrace. But for the depth and width the data are less satisfactory; and for the slope and velocity, or the height of the water surface with reference to sea-level, on which slope and velocity depended, the evidence is still more uncertain.

1. MAXIMUM HEIGHT OF THE WATERS ALONG THE VALLEY.—Before the flood had made much progress, the level of the river may have been the same with the present low-water level, or below it. And, between this condition and the end of the rise in the waters, there were successive levels along the valleys and some perhaps of long duration. There are no satisfactory means of determining the height either of the lowest or of any following stage, excepting the last—that of maximum flood.

With regard to the level of maximum flood we take the facts afforded by the heights of the normal upper terraces in the different parts of the valley. To show these heights at a glance and the continuous line of the water-surface I have plotted them for the several points of observation, together with the levels of low water and mean tide, so as to make a section of the flooded valley and stream; and this section is presented on Plate 2.

The plate contains, above the section, in figure 1, a map of

the river and its vicinity on a scale of 18 miles to the inch (or 1½ miles to the line), which extends from the village of Columbia, toward its source (about 28 miles from the more southern of its head lakes called Connecticut Lake) to Long Island Sound. The position of the western outliers of the White Mountains is seen to the east of Wells River and Haverhill. The Green Mountains, on the west, are too distant to be included. The section of the flooded stream just referred to is on the same scale as to length measured along the valley (not the river) but extends only to Stratford Hollow, 45 miles from Connecticut Lake, on account of the northeastward bend in the more northern part of the valley. The vertical scale of the section is 300 feet to the inch, or 25 feet to the line. In this section the longitudinal line AS indicates mean-tide level; BS the level above mean-tide of modern low water in the Connecticut, the figures under the line giving the same in feet for the places mentioned below; and CS′, flood-level when the flood was at or near its maximum-height. The figures directly below CS′ give the height of the surface above mean tide at each of the places stated, and those reading vertically, the difference between modern low-water level and the highest flood-level.

For the part of the section north of the Massachusetts line the levels for mean tide, low water, and maximum flood have been taken mostly from Mr. Upham's very valuable Report. But with regard to the particular terraces that mark the maximum height of the flood I diverge from him in many parts widely; and in a few other points I have depended on my own examinations. Some of these divergences I here mention in order that the nature of the changes introduced may be understood.*

The height of the "highest normal terrace" at Lancaster, according to Mr. Upham, is 30 feet above low water in the river. But the so-called "delta terrace" of Israel's Brook, just above the village, having a height of 75 feet according to his measurements (and my own), borders strictly the Connecticut River valley and was, beyond question, levelled off by the flooded river. It is the highest terrace at the place. Four miles north, at the mouth of Gaskill Brook, Mr. Upham's map has a terrace 100 feet above the river, which also borders the Connecticut valley; and 15 miles farther up the valley (3 miles above Stratford Hollow), there is a terrace 130 feet above low water. The actual height of flood-level at Lancaster and above was certainly up to the 75-foot terrace-plain, and probably up to the 100-foot, if not the still higher

* In the measurements of the heights of terraces I have used a hand-level. As the method is less exact than that employed by Mr. Upham, I have always in any remeasurements accepted Mr. Upham's results.

In speaking of a terrace, I often use the term *terrace-plain* for the plain that makes the top of the terrace, and *terrace-front* for the front slope of the terrace, the angle of which is often 40° to 42°.

130-foot; it is made 100 feet on the chart; while the 130-foot level is indicated by a dotted line. Along the Fifteen-mile Falls, between John's River and the mouth of the Passumpsic, the region of the upper falls, according to Mr. Upham, is without regular terraces; but that of the lower, below Lower Waterford, has hills and terraces of stratified drift which reach in some places a level of 200 feet above the river. So great a height here favors the view that the 130-foot level at and above Lancaster is the most nearly right. My personal observations in the valley beyond Barnet were limited to the single locality of Lancaster.

At Barnet, in Vermont, three miles below the termination of the Fifteen-mile falls, the "highest normal terrace," according to Mr. Upham, is 148 to 166 feet above low water in the river. A large upper terrace west of the village off the mouth of Stevens' Brook, (a "delta terrace" of Mr. Upham,) I found to be 198 feet above the same level; and the small uppermost plain, 225 feet. It was manifest that these plains were not distinctively terraces of Stevens' Brook; for the brook now flows over stratified drift and between bluffs of it, 70 to 95 feet below the level of these plains; and it could not have worked at terrace-making at these high levels, except by the help of the Connecticut waters. That at least the lower of the two terraces above-mentioned was strictly a Connecticut River terrace is proved by the occurrence of it two miles north along the Connecticut valley (near the mouth of the Passumpsic) with a height of 198 feet according to Upham (p. 60) above the river at Barnet, or 190 above the river abreast of the terrace. The material of the Barnet terraces is mostly loam with fine sand in straticulate beds up to the 150-foot level; and at 164 feet, just north of the village, I found a clay-bed.

At Wells River, a "delta-terrace," 263 feet above low water in the river, was found to be the true normal upper terrace of the Connecticut instead of the terrace so-made by Mr. Upham having a height of only 123 feet.

At Haverhill the "highest normal terrace" of Mr. Upham has a height, as he states, of only 83 feet. But the true normal upper terrace is over three times this height, as is shown by the position and extent of the large Haverhill terrace-plain as well as the so-called "delta-terrace" of Oliverian Brook.

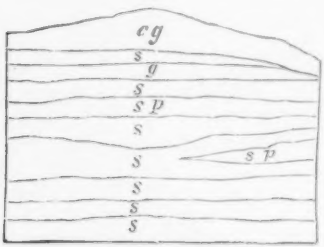
The terrace-plain on which the village of Haverhill is situated has great breadth, and continues along the Connecticut for two miles south of the village. Its height above low water in the river, by my measurement, up to a point in the street near the hotel, is 259 feet, and it rises eastward to 273 feet. Its surface consists of sand and sandy loam with some small pebbles, but becomes more stony toward the hills.

Mr. Upham alludes to the plain, but excludes it from the true terraces, stating that it is "a terrace-like area of *till*." He says that "at about one-fourth mile southwest from Haverhill village a gully recently made on a previously smooth slope, at a height

about 175 feet above the river and 75 feet below the village showed 15 feet of modified drift resting on till." What I found at the locality here (as I suppose) referred to, was a till-like deposit resting on the stratified drift. At the time of my visit in June last, there were three good sections of the terrace-formation along the road that leads north and west from the high village plain or terrace to the river-border plain, and in each the deposits were chiefly *finely-straticulate sand-beds.* In the *upper* of the three sections, exposing to view the higher 20 feet of the formation, the deposits were found to consist of sand and fine gravel, well bedded, and in part obliquely laminated.

Lower down the road, 30 to 60 feet below the top of the plain, there was a *second* section, exposing about 30 feet in height of layers of finely straticulate sands, with some that were pebbly. This stratified drift had a capping of cobblestone material which lay somewhat unconformably over the beds. The character of the section is shown in figure 1; the sand beds are lettered *s* in place of being dotted or lined, because the very delicate straticulation would be misrepresented in any engraving unless the figure were made inconveniently large. The cobblestone capping, *c g*, cuts obliquely the upper of the stratified beds.

1.



Layers of finely straticulate sand (*s*) and sand and fine pebbles (*s p*) overlaid by coarse gravel, till-like (*c g*).

2.

Section 3. Layers of sand, with some of fine gravel, finely bedded, overlaid by a till-like deposit (*c g*).

The *third* section, a few rods farther down the road, carries the section of the terrace-formation down from 65 to 90 feet from the top, or more than half of the way to the 83-foot terrace; and this was probably the position of the gully mentioned by Mr. Upham as situated about 75 feet below the village. Its beds were like those of the preceding section. The capping of stones and earth, seen in the former section, was continued here, and had greater thickness with larger unconformability to the stratified beds beneath; and some of its stones were angular and two feet in diameter. Figure 2, representing the upper half of this exposure, shows the position of this stony deposit, *c g*, in relation to the beds beneath.

This till-like deposit is thus a superficial mass lapping down the slope, quite independent of the terrace-formation; and it is there-

fore of subsequent origin. It was probably dropped by floating ice. The Oliverian Brook, which here enters the Connecticut, comes directly from the southwestern part of the White Mountains, —Mt. Moosilauke, 4811 feet high and not a dozen miles off, being its source (see map), and other peaks, 2000 to 2500 feet in height, bordering its course.* The section at the time of Mr. Upham's examination of it must have shown the till-like deposit but not the beds beneath.

On an ascent of the terrace half a mile farther south I found evidence of sand-beds and fine gravel, but saw nothing of the till-like capping; and it was evident that the latter was a local deposit. Neither did I observe evidence of it near the village over the top of the plain.

At Piermont, the "delta terrace" of Eastman's Brook, 258 feet above low water level, is so situated evidently with reference to the Connecticut valley that it should be taken as the normal upper terrace, instead of the 78-foot terrace made the "highest normal" by Mr. Upham; and at Fairlee, a "delta terrace" of Jacob's Brook, having a height of 247 feet, is the upper terrace, instead of a 57-foot terrace so made by Mr. Upham.

In the north part of Norwich, the kame, according to Mr. Upham, has a height of 189 to 224 feet above low water in the river; and the mean of these extremes, 207 feet, is not too high for flood level, and this is taken as the height instead of the 159-foot terrace of Mr. Upham.

In Hanover, the Mink Brook "delta terrace" carries the height up to 207 feet above low water in the river.

Between Hanover and White River Junction—four miles apart —there are, near midway, falls of 40 feet.

At White River Junction, the southwest kame warrants carrying the level up to 213 feet at least, in place of 177; and a terrace to the west of it makes the full height, as I found, 242 feet. The correctness of this higher level is sustained by the height which Mr. Upham gives on his map for the upper terrace and kame three miles south, in North Hartland, namely, 242 feet, and nearly by that of the "delta terrace" of Lull's Brook, 227 feet high, four miles farther south in Hartland.

In Windsor, I made measurements up to the high plain west of the village, and found it 216 feet above low water in the river, which is the height taken in place of the 196-foot terrace. The material of the terrace was fine sand and loam, but slightly pebbly in the upper portion. It is a terrace of Mill Brook, but not less so of the Connecticut.

These examples are sufficient to explain the course I have pursued.

For the height of flood-level in the part of the valley passing through the State of Massachusetts I have used some of the

* Professor C. H. Hitchcock observes, in vol. i of the Geological Report of New Hampshire (p. 217), that the Oliverian Brook in Haverhill may be expected to show signs, through boulder deposits, "of a local glacier descending the west flank of Moosilauke."

measurements of Professor Edward Hitchcock, and for the Springfield region, the survey of the Springfield City Engineer, as in a former paper.* I have personally made levelings in Holyoke, Willimansett, and South Hadley. It was my purpose to have made further observations in the State, but finding that Professor B. K. Emerson, of Amherst College, was engaged in a thorough study and mapping of the terraces, I gladly left the subject in his hands.

The height of the very extensive upper terrace of western Northfield, the town adjoining New Hampshire, I have taken from Mr. Upham, his map covering this Northern Massachusetts town; he gives it at 198 to 213 feet above low water in the river. Although the terrace borders most obviously the Connecticut valley, he speaks of it as a tributary's terrace, and takes for the "highest normal terrace" one only 128 feet high above the river. The true upper terrace extends to Gill; and a corresponding one on the eastern side of the Connecticut, but little lower, continues with small interruptions all the way to Miller's Falls.

For the height of low water level in the Connecticut Valley, between Holyoke, in Massachusetts, and Hartford, Connecticut, I have used the section made in connection with the very exact survey of General Ellis, making part of the Report† of General Warren for the year 1878. The height for the river above Holyoke has not yet been accurately determined. In the section, the height at the top of Turner's Falls is made 180 feet, and at the foot of the rapids, 120 feet.

In the Connecticut part of the section, the heights are, with one exception, from my own levelings. My former measurements have been repeated, in order to be able to refer the heights to mean-tide level, and others have been made.

The extensive terrace east of the Connecticut, which commences 8 miles north of Springfield and has a width in Massachusetts of 2 to 6 miles, with an average height of 180 feet above mean tide, extends as many miles into Connecticut, and east of Thomsonville spreads eastward half a mile beyond Hazardville, or 4½ miles, with a height of about 160 feet. It is in general a plain of unfertile sands, but fine-pebbly on some higher portions. It seldom rises to the level of maximum flood. Just south of Thomsonville, this upper plain appears about the isolated Enfield ridge, at a height of 214 feet. Two miles west of the Connecticut, nearly opposite the latter place, it has full height, 215 feet, about the isolated ridge of Suffield village. The material is coarse gravel. A northern portion of the Suffield ridge is 10 feet higher and is of coarse cobblestone material, and may be till.

Northwest of Hartford, the upper terrace is well defined half

* Southern New England during the melting of the Great Glacier, this Journal III, x and xi, 1875, 1876.

† Annual Report of the Chief of Engineers for 1878. Appendix B 14. Report of the surveys and examinations of the Connecticut River between Hartford, Conn., and Holyoke, Mass., made since 1867, by Brevet-Major General G. K. Warren, Major of Engineers, U. S. Army.

a mile from the gap through the trap for the Farmington River, and has a height, by aneroid, of 210 to 215 feet. The plain in the vicinity of the Manchester depot, on the east of Hartford, is about 200 feet in height.

South of Hartford, east of the Connecticut, in Glastenbury, a broad terrace rises abruptly from the river and spreads two to three miles eastward, with a height of 170 to 190 feet. Two miles north of Middletown it is reduced to a broad shelf against the eastern hills, a mile or more from the river, and has a height of 186 feet above mean tide east of Gildersleeve's landing.

At Middletown, where the river turns eastward to pass the Narrows, the waters spread 2 to 4 miles west of the Connecticut. At Rock Falls, and just beyond, the terrace deposits have a height of 193 to 199 feet above mean-tide; and at Pine Grove Cemetery the wide plain is, according to an aneroid measurement by Professor Wm. North Rice, of Middletown, 199 feet.

The facts make the maximum height at Middletown probably between 193 and 199 feet.

Nearly two miles southwest of Middletown, just east of the Haddam road, stratified sand and gravel make the upper part of a hill which is 235 feet high above mean tide. If a part of the terrace-formation, it would make the maximum level of the flood and of the Middletown dam 40 feet above the height just mentioned. But it has a capping 3 to 4 feet thick of coarse unstratified material containing some scratched stones, and is probably of earlier origin. The hill stands between higher, rounded, till-covered hills on the west and east, with low, marshy land adjoining, and between a wide region of lower land to the south (the Johnson Lane district), and the valley of the Connecticut to the north and northeast; and if waters were above 200 feet over the region, they would there flow across to the Connecticut. The conditions of origin are not easily explained.

The height of the line of flood-level in the section on Plate 2 is in several cases below that which the highest terrace-plain seems to authorize. Thus, at Haverhill, the upper terrace-plain has for its highest part to the eastward 673 feet, 10 feet above the height in the section; at Brattleboro, where 410 feet is taken for the height of flood-level, a terrace occurs according to Upham's map, of 425 feet; at Dummerston, 5 or 6 miles north, there is one either side of the stream of 420 to 440 feet; in Northfield the terrace rises toward the hills 15 feet above the level taken for the upper level; and so in several other cases. It is quite common for a terrace-plain to rise in level above the average height as it nears the hills: and as this may come in part from material carried down the slopes at the time of the flood and washed over the surface raising it above true flood-level, I have not generally taken the extreme height thus afforded. Moreover the terraces of tributaries often rise rather rapidly where within a confined valley, owing to the great amount of transported material. I have sought to be rather under the true height than above it in

all judgments. It is quite possible, however, that a more exact study of the terraces will place the flood-level higher than I have done; certainly higher, I think, rather than lower.

The section gives an impressive idea of the greatness of the ancient flood. The river had, as it shows, two great falls in its course, one, the Fifteen-mile Falls to the north, below Lancaster, the other a twenty-five mile fall on the way to the Sound from Middletown, Connecticut. It took its full magnitude west of the White Mountain region, after its junction with the Passumpsic, one of its two chief sources, and after accessions from its other head waters, Stevens' Brook and Wells River on the west, and the Ammonoosuc River and Oliverian Brook on the east. At North Haverhill the height of the water above modern low-water level was at least 250 feet, and its width exceeded two miles; and it was nearly or quite 200 feet above the same level at Middletown in Connecticut, 172 miles south of Haverhill and 26 miles in a direct line along the valley, from the Sound. The diminution in depth southward was evidently a consequence of the increasing width, especially after entering Massachusetts.

The Fifteen-mile falls were long rapids over a nearly continuous slope of coarse till, showing abundant bowlders but with scarcely any exposures of solid ledges.* The falls below Middletown began in a plunge over a dam 190 feet high above modern low water, that was formed at the Narrows—a cut, but 650 feet wide in its lower part, through a high rocky ridge of crystalline schists and enormous granite veins. Below the dam the descent in the waters is registered in the terraces of the valley (see section on Plate 2); and it is shown thereby to have been gradual and not a vertical plunge. The dam was probably an ice-dam as explained in a former paper.† Above the dam the waters spread westward over the Middletown region to a distance from two to four miles, covering the tops of some prominent hills. Yet those of the hills that are within one to two miles of the river are mostly free from stratified drift and terraces, and have instead rounded surfaces and a deep covering of till; and it may be that this scoured condition was produced by the violent rush of the waters at the final destruction of the ice-dam.

To enable the reader to compare the ancient with the modern floods of the Connecticut, a section of the latter from Holyoke to Long Island Sound is given on the general section. For the part from Holyoke to Hartford it is taken from the section published in General Warren's Report as the result of a series of careful measurements by General Ellis. For the

* Report of Mr. Upham, p. 24. † This Journal, III, xi, 178, 1876.

height at Middletown I have taken the height of the highest modern floods at that place, 25¾ feet. These high floods of modern times are largely dependent for their height on obstruction by ice at the Narrows, like those of more ancient time.

The comparison which may thus be made can give but a feeble idea of the actual contrast. The modern stream in its greatest floods retains still its tortuous course and abrupt bends, and the great width it takes in some parts is made by the spreading of only a thin layer of water over wide flood-grounds. But in the time of the great flood, the river for the most part rose above such obstacles, took the wide valley for its channel, and had an almost unimpeded course on its way to the ocean. In figure 4 on Plate 2, an enlarged map of the river-valley from Wells River to a point below Bellows Falls is given (from a map of the Atlas accompanying the New Hampshire Report). It shows by the dotted line either side, the east and west limits of the terraces, and thus indicates something of the extent to which modern bends were absent.

On the other hand the height of the flood as exhibited in the section is greatly exaggerated compared with the length—though hardly so if measured by the impression which the high terraces make on the mind of an observer. To aid the reader in eliminating this exaggeration, a section of a small portion of it with the natural pitch is given on the plate in fig. 3, below the general section of the river. This section represents the "Fifteen-mile Falls," along the twenty miles between the mouth of the Passumpsic and St. Johns River. According to Mr. Upham's Report, the whole fall in the 20 miles is 370 feet; the upper fall, 156 feet; the lower, 183 feet; and the descent between the two falls, 31 feet.

Some additional exaggeration is made apparent in the course of the following discussions.

From the facts presented in the section and others connected with the Connecticut valley and its terraces, we may obtain approximate results with regard to the *mean depth* of the flooded river, its *mean width*, the *mean slope* or pitch of the stream, and its mean *velocity*.

2. Mean depth.—In seeking to ascertain the mean depth of the flooded river at any place, we cannot rightly measure down to modern low-water level. For over the bottom of the valley, there is very commonly a wide terrace 60 to 80 feet above low-water; and, when the flood was far advanced, this terrace-plain may have extended across the narrow channel of the modern river and obliterated it. On account of the wide extent of this lower terrace, it appears to be necessary to deduct 60 to 80 feet from the whole height of the flood in most parts

of the valley; and for the sake of an estimate and not an over-estimate, 75 feet may be the amount deducted.

According to the section, the height above modern low-water level at Haverhill was about 260 feet; and this, diminished by 75, gives for the depth 185 feet. So we obtain for Hanover and White River Junction, if the height of the intervening falls be divided between them, 225–75=150 feet; for Windsor, 216–75=141 feet; for Brattleboro, 210–75=135 feet; for South Vernon, near the border of Massachusetts, 207–75=132 feet.

We may thence take for the average depth north of the Massachusetts line, 140 feet. The depth on the southern boundary of Massachusetts obtained by the same method would be 125 feet, and at Hartford in Connecticut, 125 feet. But the width is so much greater after entering Massachusetts, that it is quite certain, as already stated, that the less depth is more than balanced by the greater width.

3. MEAN WIDTH.—In order to obtain an approximation as to the mean width of the flooded stream between Wells River and the Massachusetts line, we may review, for a few localities, not only the width (which I take from Mr. Upham's map), but also the areas of cross-sections.

At Haverhill, the highest normal terrace of the east side rises nearly to its full height, 263 feet above low water level, directly from the lower terrace-plain of 83 feet. The width of the channel-way on the map, above the 83-foot terrace, is 4,000 feet. Taking for the depth of water 263−83=180 feet, the area of the cross section, with this width, would be 720,000 square feet.

Between northern Orford and Fairlee, 8 miles south of Haverhill, the higher terraces are wanting. Taking for the width only that covered by the valley deposits, that is, the low terraces—it is about 3,300 feet—which is too low, because there is no high terrace to mark the actual width, and the low terraces referred to are only 55 feet above low water. The height of the flood as given in the section, Plate 2, is 252 feet; thence, with the depth (252−55=) 197 feet, and with 3,300 feet as the width, the area of cross-section is 650,000 square feet.

Where the valley passes Norwich and Hanover, the most prominent terrace has a height of about 150 feet above low water in the river, while the upper one, marking flood limit, is 210 feet. The channel-way has hence a narrow *lower*, and a wide *upper* section. For the width of the former, I have measurements obtained for me by Prof. R. Fletcher, of the School of Civil Engineering at Dartmouth College. The measurements were taken between points half-way up the steep terrace-front.

600	feet below	the bridge	crossing the river,	width 1,980 feet.
400	feet above	"	"	" 1,350 "
800	"	"	"	" 1,270 "
2,500	"	"	"	" 1,000 "

The mean of the above numbers is 1,400 feet. At the last of the localities, the river has on its west side high rocks and therefore no terraces, and the bottom terrace is only 30 feet above low-water level. This number should, therefore, be thrown out, the small width having probably been compensated for by increased velocity. In this case the estimated mean width would be over 1,500 feet.

For the width of the upper section of the flooded stream, or that above the level of the 150-foot terrace, we have the interval between the highest terraces of the two sides of the valley in the line of the villages of Hanover and Norwich, 8,000 feet; and on a transverse line 2,500 feet below the bridge (see above), 4,000 feet. The mean between the two is 6,000 feet. To obtain the area of a cross section we have then 1,500 feet for the mean width of the lower section of the flooded stream, and 6,000 for the upper. For the depth of the lower section, we deduct from 150, 47 feet, this being the height above low water of the higher of the bottom terraces, and obtain 103 feet; and for that of the upper, 210−150=60 feet. The area of the whole cross-section, afforded by these numbers, is 514,500 square feet. The falls of 40 feet in the river, two miles below Hanover, suggest a good reason for the little height of the lower terraces.

Above Brattleboro, the mean width, as nearly as we can obtain it from Mr. Upham's map, is 5,000 feet. The depth, deducting 75 feet for the lower terrace, is 135 feet; and this gives for area of cross section, 675,000 square feet. At the narrowest part 3 miles north of Brattleboro, the width of the channel-way is 3,500 feet; but this is so only for a short distance, and the lower terraces here have a height of but 35 to 50 feet. With this width and deducting only the mean between 35 and 50, or 43 feet, for the lower terrace, the area of section is about 585,000 square feet.

From these results, although not based on accurate measurements, we may conclude that the area of cross-section for the Connecticut, between Wells River and the Massachusetts line, averaged *at least* 560,000 square feet, and hence that the mean width, if 140 feet be taken as the mean depth, was probably not less than 4,000 feet.

4. Mean Slope.—We may *first* deduce the slope or pitch on the assumption that the land and ocean had their present relations as to level; and then, *secondly*, consider the evidence as to these relations having been different from now, and *finally* make other calculations in accordance with the conclusion reached.

A. *Mean slope of the river in case the land and ocean had their present relations as to level.*—Supposing the land and ocean in the era of the flood—the early part of the Champlain period—to have had their present relative level, the slope of the stream may be taken directly from the section on Plate 2, the figures along the upper line giving the height at different localities along the valley, and those by the lower lines the distances as *measured along the valley* (taking no note of the turns in the river) between localities, on a scale of a twelfth of an inch to 1½ miles. We thus find for the slope:

	Distances in miles.	Slope per mile.
Haverhill (655 ft. flood-level) to Windsor (520),	41	3·3 feet.
Windsor (520) to South Vernon, Vt. (396),	49	2·5
South Vernon (396) to Springfield, Mass. (240),	44	3·5
Springfield (240) to the Middletown Narrows (195),	38	1·2
Narrows (195) to Long Island Sound,	26	7·4
Haverhill (655) to the Middletown Narrows (195),	172	2·7
South Vernon (396) to the Middletown Narrows (195),	82	2·5
Haverhill to the Sound,	198	3·3
South Vernon to the Sound,	108	3·6

From the above it appears that, except for the dam at the Middletown Narrows, the mean slope from Haverhill to the Sound would have been 3·3 feet per mile, or the same as from Haverhill to Windsor. But, owing to the dam, the mean slope to Middletown is but 2·7 feet, while below the Narrows it is 7·4 feet per mile.

B. *Mean velocity.*—To obtain the velocity, we have the data above deduced for the mean width, depth and slope of the flooded river.

Another element required is the amount of resistance from bends and obstructions in the stream. It is fortunate for the calculations that the Connecticut valley follows a remarkably straight north-and-south course. With the water raised 200 feet and more above modern low water and a width thereby averaging nearly a mile along the course north of Massachusetts and more than this south, the bends are only those of very large curvature, which would not affect greatly the velocity of a rapid stream. On the map of the river and valley between Wells River and Bellows Falls, figure 4, Plate 2, the band covered by the deposits, indicated by the dotted outline, shows that the waters made *nearly a straight stream.* The map is somewhat short of the truth, since the upper terraces are absent in parts of the valley and particularly so for the narrower part along from Ely to Piermont. Only a map that gave on each side of the valley the contour-line corresponding to the height of maximum flood, and also the limits of the channel-way as marked by the inner limits of the highest terraces, would show fully the degree of straightness.

Below Windsor there is a prominent obstruction in Mount Barber, an elevation in the direct course of the stream and a mile wide; but there was abundant room for the river on either side of it. Another obstructing mass of ledges probably existed just south of Turner's Falls southwest of the mouth of Miller's River, in Massachusetts, ten miles south of South Vernon, where the Connecticut river makes a westward bend of six miles to Greenfield. This *probably existing* "mass of ledges," is now beneath the terrace formation, the top of which is the elevated plain between Montague City and Miller's river; and its existence at no great depth beneath the plain is inferred from the terrace deposits—on the ground that these are an indication of slackened flow in the waters. The flooded river passed both along the east and west sides of these obstructing ledges, as well as over them at highest water. After passing this place, the river at highest flood had an open and almost straight way to Middletown, which was nowhere less than 4,000 feet in width, though narrowed at Mt. Holyoke, Enfield Falls and Glastenbury.

Whenever a careful topographic survey of the Connecticut valley shall have been made, which shall lay down throughout it contour-lines corresponding to the maximum flood-level, it may be possible to arrive very nearly at the amount of resistance produced by the flexures. At present it is not possible to reach any accurate estimate: and the best that we can do is to use a diminished width for the basis of the calculations and make a further allowance by estimate. The results with regard to the velocity are hence obtained below for the river with a breadth of 2,500 feet, as well as with that of 4,000 feet.

The formula for the calculation of the velocity here employed is that given by Humphreys & Abbot for large rivers in their admirable Report on the Mississippi River, numbered 41, on page 312. It is applicable strictly to a limited portion of a large river without bends. It is as follows:

$$v = ([225r, s^{\frac{1}{2}}]^{\frac{1}{2}} - 0{\cdot}0388)^2$$

in which v is the velocity sought: s, the sine of the slope: and r, the mean radius = area of cross-section, a, divided by $p+W$, or the length of the wetted perimeter (p) *plus* the width at surface. In the general formula, the sine of the slope $= s = \frac{h'}{l}$. l = length of limited portion of the river. $h = h_{,} + h_{,,}$ = difference of level of the water-surface at the two extremities of the distance l, in which $h_{,}$ = the part of h consumed in overcoming the resistances of the channel supposed to be straight and of nearly uniform cross-section, and $h_{,,}$ = the part of h consumed in overcoming the resistances of bends and important irregular-

ities of cross-section. In the equation for large rivers, above quoted, $h_{''}$ is thrown out by the conditions.

The following are the results for the portions of the river indicated in the column to the left. The slope is given in feet per mile. The velocity is stated in miles per hour and in feet per second, and both for a width of 4,000 and 2,500 feet.

		Velocity, width 4000 feet.		Width 2500 feet.	
	Slope.	In m. per hour.	In ft. per second.	In m. per hour.	In ft. per second.
Haverhill to Windsor	3·3	13·07	19·16	12·93	18·97
Windsor to South Vernon	2·5	12·18	17·87	12·06	17·69
South Vernon to Springfield	3·5	13·26	19·45	13·13	19·25
Springfield to Middletown dam	1·25	10·23	15·00	10·12	14·85
Haverhill to Middletown dam	2·7	12·42	18·22	12·30	18·03
South Vernon to Middletown dam	2·5	12·18	17·87	12·06	17·69
Middletown dam to the Sound	7·4	16·02	23·49	15·85	23·25

From the above, the mean velocity for the whole river from Haverhill to Middletown, would have been, assuming that the relations of the land to the sea-level were the same as now, over 12 miles an hour, even supposing the mean width to have been but 2,500 feet.

This great velocity, or even one of 10 miles an hour, is not compatible with the character of the deposits which lie at different levels beneath the surface of the stream—both those at 140 feet below the surface and those at higher levels. The former, away from the region of the mouths of tributaries, consist almost uniformly of nearly incoherent but stratified sand, or sandy loam, and in some parts of clay: and similar fine materials in general constitute the terrace-deposits of the higher terraces (including the terrace-fronts) up to a level within 50 feet of the highest flood level and often nearly to the uppermost plane.*

According to trials, a current of *one-third of a mile* per hour will take up and transport fine earth or clay having the particles ·016 inch in diameter; and one of *two-thirds*, fine sand, the mean diameter about ·064 inch. Accordingly, since the mean diameter of the largest transportable particles varies as

* Darcy and Bazin, in their *Recherches Hydrauliques*, give the following as the bottom velocity (in feet per second) at which scour commences for the different materials mentioned, and the corresponding calculated mean velocity.

	Bottom velocity.	Mean velocity.
1. Earth	0·26	0·33
2. Loam	0·50	0·65
3. Sand	1·00	1·30
4. Gravel	2·00	2·62
5. Pebbles	3·40	4·46
6. Broken stone	4·00	5·15
7. Chalk	5·00	6·56
8. Hard rock	10·00	13·12

—Cited from the Encyl. Brit., vol. xii (1881), Art. Hydromechanics.

the square of the velocity (supposing them of like density) a stream of 2 miles an hour at bottom would carry along stones of about 0·6 inch in diameter; and one of 4 miles, stones $2\frac{1}{8}$ inches in diameter. The mean velocity is generally about a third to a sixth greater than the bottom rate, the differences diminishing as the velocity increases. If the mean velocity were 10 miles an hour, that of the bottom would be over 8 miles (unless greatly impeded by transported material)—rapid enough to scour down to stones and solid rock.

This argument is not based on the depositions made by the stream; for these were more or less made over the flood-grounds of the river as the waters rose; and the waters over flood-grounds, even in the case of rapid streams, are variously impeded by the amount of transported material, friction in the shallow waters, and obstructions, often dam-like, due to the uneven surface beneath; but on the transporting force of the stream at the time of maximum flood, when all the terrace-plains except the very highest were swept by the flowing waters. It may be questioned whether the lower terrace of 60 to 80 feet above present low water, which is almost everywhere —if the mouth of no tributary is near—made of sand or loam where not of clay, was actually the bottom of the flooded stream: whether, the waters did not excavate down to stones and rock, so that this terrace is of subsequent formation. But this supposition does not rid the subject of the fact that the flooded stream did not take up and carry off the sands of its bottom. For the range of higher terraces usually 140 to 160 feet above low water in the river, were at the time under 50 feet in depth of water; and these, away from tributaries, usually consist at top and below of fine sand or loam, or of fine gravel. The great terrace-plain north of White River Junction was one of this kind with 50 feet of water above it; and it consists at surface mostly of fine sand or sandy loam, with some portions of fine gravel; and, below the surface, except near the river, chiefly of sand with some clay. The materials of the corresponding terrace near Windsor are still finer. The high terrace-plain east of Greenfield and south of Turner's Falls, between Montague City and Miller's Falls, called the Montague City plain, lies directly in the way of the Connecticut, as stated on page 191; and although flowed over at the highest flood by water 10 to 30 feet in depth, it consists chiefly of fine sand, or loamy sand, with some clay, except on its eastern and north-eastern side, where it received contributions from the violently torrential Miller's River.

Thus all parts of the valley bear like testimony to a velocity in the waters at maximum flood which was not great enough to carry off fine gravel, and this means a velocity not exceeding

two miles an hour at bottom: which is the condition in a stream having a mean velocity of 3 to 4 miles.

The transported materials in the waters would have had a retarding effect; but small, since as already shown, they were only sand and finer material, and the fine straticulation indicates a free-flowing stream (p. 93). The deduced mean velocity, over 12 miles an hour, could hardly have been reduced by all the causes of retardation together to less than 9 or 10 miles an hour.

We are thus led to enquire what range of evidence there may be as to the existence of a less pitch in the valley, to cause the less velocity, or as to any other method by which a diminished velocity might have been produced.

One method is by means of *dams;* a second, by *changed relations between the level of the land and sea.*

B. *Dams on the Connecticut Valley as a possible source of less slope in the waters.*—That it may be understood what is to be explained by means of dams, or in other ways, we here review the facts with regard to the clay-deposits and associated sand-deposits of the valley.

It is to be remembered that the sand-beds and those of finer material ordinarily make not only the lower terraces but also the highest, where tributaries are absent, to within 50 and often 20 or 30 feet of their tops: and that this is so even high up the Connecticut, as at Barnet, not two miles south of the junction with the Passumpsic, where these finer deposits extended to a level of 150 to 200 feet above low water in the river.

Clay-deposits are widely distributed about Hartford to a height of 75 feet and less above tide level, or low water in the river. At Springfield, 58 miles in a direct line from the Sound, they are of great extent at a height of 170 feet above the sea level; at Holyoke, 8 miles north, on the west of the Connecticut, and at Willimansett, nearly opposite, on the east side, at 175 feet: on the eastern slope of Mt. Tom, south of Northampton, according to Professor E. Hitchcock, at 178 feet; and over the Amherst region, as I learn from Professor Emmons, of Amherst, at nearly the same level. The dam below Middletown suggests a possible explanation of the origin of quiet water for the making of the clay beds about Hartford: for if the dam were but little more than a third of its final height it would be sufficient; and if raised to within 10 feet of its full height, it might have produced the quiet movement in the waters required for all the clay-beds up to and including those of the Amherst region. That the height of the dam was actually so near its extreme height, when the terrace deposits

of Springfield were 50 feet and more below their maximum height, is far from certain. The Springfield, Willimansett and Amherst deposits are situated close by the present river channel, and hence seem to be safe evidence as to the very small velocity of the river, which they might not be if they were more distant flood-ground deposits.

Clay-beds exist just *below* the Middletown dam, on the eastern or Portland side, to a height of 75 feet above modern low water, in a very steep and short valley. The place would seem to be very unfavorable for such fine depositions if the dam were then formed, and especially if at its final height. But it is possible that the ice had made a barrier to the little stream, so that the evidence from these clay-beds is not conclusive against the existence of the dam during their formation.

But, further, extensive clay-beds exist in the high and broad terrace of Montague City, east of Greenfield, 300 feet above tide level. Again, on the terrace-plain, between Windsor and Hartland, 500 feet above the sea-level, or 190 feet above the river, clay comes to the surface in a field so as to be turned up (as I observed) by a plough, the material along the plain elsewhere being fine sandy loam. South of this, in Windsor, the deposits are fine loam and sandy loam to a height of 500 feet, with clay nearly to this height. North of White River Junction clay was exposed near the river at a height of 460 feet above mean tide, or nearly 130 feet above the river at low water. In Hanover, N. H., the clay-beds extend along for 3 or 4 miles or more; and in the village they reach a height of 523 feet above mean tide, or 150 feet above the river—clay having been taken out at this level in excavating for the cellar of Professor Hubbard's house (as he informs me), opposite the northwest corner of the College Square; and on the opposite side of the Connecticut, in Norwich, there are clay beds at corresponding heights up to 500 feet. Just north of the village of Barnet a clay-bed comes to the surface in the terrace-plain near the river at a height of 610 feet above mean tide and 158 above the river. These few examples will no doubt be multiplied greatly by careful exploration.

For making the clay-beds north of Amherst, the Middletown dam would have been of no avail; and besides this dam there is no satisfactory evidence of any other. This is shown by the regularity in the pitch of the terraces along the valley. The valley is comparatively narrow between Mt. Holyoke and Mt. Tom; but the heights of the terraces give no evidence of a dam, and the clay-deposits are at nearly the same high level above and below. Another narrow way for the modern river is between Mt. Toby and Sugar-Loaf, a dozen miles north of Mt. Holyoke; but here the waters of the flooded river

had a passage east of Mt. Toby, and a very wide one west of Sugar-Loaf. There are like objections to the location of dams at other places. Mr. Upham says, on this point, especially with reference to the part of the valley north of Massachusetts, that the idea of dams along the valley is not sustained by the topography of the valley or the distribution of its terraces.

As dams have, therefore, not existed where they would have been needed to reduce the slope of the stream and make a velocity that would admit of extensive depositions of sand through all the valley and of clay-beds in many parts to various heights up to 610 feet above the sea-level, we may consider what effect may have come from changed conditions in the level of the land and sea.

C. *Slope and velocity under changed relations in the level of the land and sea.*

a. *Evidence of a change afforded by the heights of Elevated Sea-beaches.*—The fact of a wide difference between the flood era and modern time along the coast region is put beyond question by the heights above existing tide-level of shell-bearing beach-deposits.

The facts are well known. The more important are here tabulated:*

	Latitude.	Height.
New Haven or New London, on the Sound	41° 14′	15 to 25
Sankaty Head, Nantucket	41° 17′	45
Point Shirley, near Boston	42° 19′	75 to 100
Lewiston, Maine	44° 6′	200
Mt. Desert, Maine	44° 20′	217
Colchester, Vt., (4 m. N. of Burlington, on L. Champlain)	44° 33′	335
Middlebury, Vt.	44° 10′	403
Montreal	45° 31′	520
Les Éboulements, on St. Lawrence River	47° 30′	about 600
Murray Bay, on St. Lawrence River	47° 45′	about 600

The facts prove (1) a difference of level compared with tide-level between the era of the beach-deposits and the present; and (2) an increasing amount of difference northward. They are all from the coast it is true, but from the coast of the northwest side of New England as well as from its eastern, southeastern and southern borders; and in view of their wide geographical range, and especially the fact, already made manifest, that the valley of the Connecticut must have had diminished pitch during the era of the flooded river, we may believe that the interior of New England experienced the changed re-

* The heights at Éboulements and Murray Bay, on the St. Lawrence, I have received from Dr. J. W. Dawson, of Montreal. The beds at Middlebury, Vermont, are of clay without marine shells; but, according to Professor C. H. Hitchcock, there is no higher land between them and Lake Champlain, and they could not have been made unless the waters of the lake were at the same level. The heights on Long Island Sound (north side) are based on stratified deposits along or near the Sound, but not shell-bearing. The shells in the Mt. Desert deposits indicate a considerable depth of water.

lations to the sea-level that we find indicated along the sea-coasts.

It being thus altogether probable that the *interior* of the country participated in the change, the amount of this change along any diameter would probably have had some relation to the amount at its extremities. As Montreal and Lake Champlain lie on the west side of the area, Murray Bay on the north, and the Atlantic border deposits on the eastern, several such diameters may be run across. From the heights observed (p. 196), and the distances between any two of them, the mean rate of increase per mile of distance may be obtained. The following tables contain the results of such comparisons—substituting New Haven, Ct., or New London, Ct., for the north shore of Long Island Sound.

A. Lines running toward Montreal.

	Distance.	Rate.	
New Haven to Montreal	300 miles.	1·66	feet per mile.
Point Shirley to Montreal	255 "	1·65–1·75	"
Lewiston, Me., to Montreal	195 "	1·5	

B. Lines to Murray Bay.

New Haven to Murray Bay, Canada	460 miles.	1·25	feet per mile.
Point Shirley to Murray Bay	375 "	1·33–1·40	"
Lewiston to Murray Bay	260 "	1·44	

C. Lines to localities on the Atlantic Border.

New London to Lewiston, Me.	220 miles.	0·9	feet per mile.
Sankaty Head to Lewiston, Me.	192 "	1·05	"
Point Shirley to Lewiston, Me.	125 "	1 to 1·2	"
Sankaty Head to Point Shirley	70 "	0·5 to 0·8	"

The mean rate of increase toward Montreal is thus 1·5 to 1·75 feet per mile, while on the coast it is not over one foot a mile; and in the direction of an intermediate point, Murray Bay, it is 1·25–1·40 feet per mile. The *direction of greatest increase is not in the direction of a meridian, but along a line running northwestward.*

From these mean rates of increase, supposing the increase uniform, the amount of change at intermediate points on the lines may be obtained. We thus obtain for the region of the Connecticut Valley at Lancaster, using the line from Lewiston to Montreal, a height of 318 feet. Using thel ine from New Haven to Murray Bay for a similar calculation, the height for the same place is found to be 326 feet. This near coincidence seems to be significant.

For Haverhill, the amount of change would be—the place being 46 miles from Lancaster, measured along the valley, and 198 from Long Island Sound—272 feet.

We thence have 1·25 feet per mile (=50 seconds nearly in angle) as the mean rate of change northward along the Connecticut valley.

The line D S on the section (figure 2, Plate 2) represents the mean-tide level thus deduced. It is drawn from a point on the Sound marking 25 feet above mean-tide level (supposing the change on the Sound to be 25 feet, though along by the mouth of the Connecticut it may not have exceeded 15 feet), and rises in the direction of the valley northward, at the rate of 1·25 feet per mile.

It cannot be assumed that the rate was equable throughout the valley. It may have been less than the deduced rate to the south, and greater northward; and this is shown beyond to have been probably a fact. If the rate had been one foot per mile for the first third of the length of the valley, or to Springfield, and 1·33 feet for the rest of the way to Haverhill, the height at Haverhill would have been very nearly the same as above deduced, or 268 feet.

b. Effects of the change while the river was low.—If, the river were, for a while, at or near modern low-water level (and it probably was so), the change of 1·25 foot a mile, would have taken out all the mean slope from the several parts of the valley, excepting the abrupt descents at the falls. The tides would have extended beyond the Holyoke dam, eight miles above Springfield, obliterating the falls and have stood 15 feet above its top; and have reduced Turner's Falls nearly 30 feet in height. The elevation of low-water level above the sea would have been only 35 feet at South Vernon, or the Massachusetts boundary; at Windsor, 83 feet; at Haverhill, 120 feet. Hence the descent between South Vernon and Windsor would have been only 48 feet, which is three feet less than the fall (51 feet) at Bellows Falls, situated between these two points; and the descent between Windsor and Haverhill would have been only 37 feet, which is three feet less than the fall (40 feet) at the falls between Hanover and White River. Since these falls would have wasted, by friction at bottom, any velocity which might have been gained by descent, the Connecticut River would have been for the most part a series of nearly still-water stretches with falls at a few distant points. This condition would have continued, with but little change as to the effect of the dams, after the waters had risen 20 to 25 feet above low water, as in a modern flood.

One possible consequence from such a state of things would have been an opportunity for clay and fine-sand depositions, without the need of help from dams; and another, an almost complete absence of the work of erosion—since the waters would

have had but slight working force, and the present low-water level would have been the lowest possible level at which this little work could have been done. An earlier consequence might have been—the deposition of the till with no more stratification where it fell into the waters than when dropped outside of them.

c. Effects of the change after the flood had made progress.—When the river had risen to a height of 60 or 80 feet above low-water level, the falls in the course of the valley would no longer have been mere nullities as regards their effect on the mean velocity of the stream immediately below them; for the velocity acquired by the descent would have been only in part wasted by friction at bottom.

But when, beyond this, maximum flood level had been reached, so that the surface of the water was 200 feet and more above low-water level, the falls would have lost all influence on the velocity by their submergence, and the general slope of the flood would have conformed nearly to the general pitch and width of the valley. As the upper deposits were made by the stream when near and at this maximum level, and the lower were, at the same time, beneath the sweeping flood, it becomes of the highest importance to compare, as nearly as possible, the mean velocity at the time with the amount of transporting power indicated by the nature and condition of the stratified deposits.

If the rate of change along the valley with reference to the ocean level were, as above deduced, 1·25 feet per mile (and the change at the Sound 25 feet,) the height of the water-surface above mean tide would have been at—

Haverhill	383 feet.
Windsor	299 "
South Vernon,	236 "
Springfield,	135 "
The Middletown dam	137 "

The mean slope and velocity on the above supposition, would hence have been for the part from—

	Distance in miles.	Slope ft. per m.	Velocity, with width 4000 ft. m. per h.	Velocity, with width 4000 ft. ft. per sec.	Velocity, with width 2500 ft. m. per h.	Velocity, with width 2500 ft. ft. per sec.
Haverhill to Windsor	41	2	11·515	16·89	11·39	16·70
Windsor to South Vernon	49	1·3	10·33	15·15	10·22	15·00
S. Vernon to Springfield	44	2·3	11·93	17·50	11·81	17·32
Springfield to Middletown	38	0	----	----	----	----
Haverhill to Springfield	134	1·9	11·37	16·67	11·25	16·50
Middletown dam to Sound	26	5·2	14·65	21·49	14·51	21·28

According to the above, the river at maximum flood would have had no slope between Springfield and Middletown, and have therefore been in this part a great lake. But this condition

is shown to be improbable by the coarse character of the deposits in the Springfield region that were made at maximum flood; and this is one of the reasons referred to on page 198, for believing that the slope in the lower third of the valley was reduced to a less rate than 1·25 feet per mile. Taking it at 1 foot per mile to Springfield, as there suggested, and 1·33 feet above Springfield, it gives for the height of the water-surface above mean tide at

Haverhill	387 feet.
Windsor	307 "
South Vernon	248 "
Springfield	151 "
The Middletown dam	144 "

Excepting south of Springfield, the changes in slope thus introduced between the places mentioned are small—that from South Vernon to Springfield becoming 2·2; from Windsor to South Vernon 1·2; that from Haverhill to Springfield, 1·8; and that from Haverhill to Windsor continuing at 2; so that the velocities would be but slightly altered. Between Springfield and Middletown the pitch becomes about 3 inches a mile.

According to the preceding table, the velocity from Haverhill to Springfield, notwithstanding this change of one-third in the slope of the stream, would still, when at the highest flood-level, have exceeded 10 miles an hour for a mean width of 2500 feet, the pitch to Springfield being nearly 2 feet a mile.* And if we assume that bends and other obstructions, and transportation would have reduced the mean velocity 20 per cent, it would still be 8 miles an hour, with a bottom velocity over 6, and therefore much in excess of that indicated by the character of the bottom deposits.

It is quite certain that the slope must have been much less than that which corresponds to a height of water-surface at Haverhill of 387 feet, or a pitch in the valley to Springfield of 21 inches a mile. But it is not so evident what slope would harmonize the facts; that is, would cause a velocity sufficient to make or leave coarse valley deposits near and at flood level, such as might be made by a current of 4 to 6 miles an hour, and, at the same time, leave almost undisturbed beds of sand or of fine pebbles along its bottom, whether at depths of 50 or 150 feet, this alike for the stream north of South Vernon and south of it, and even for the part north of Wells River to Barnet as well as south of Wells River.

By calculation, using the same elements as before, taking the width at 2500 feet and making no allowance for ob-

* According to the formula, the velocity varies approximately as the 4th root of the slope, and, consequently, to diminish the velocity from any rate to one-half, the slope must be reduced about a sixteenth.

structions by bends or transportation, it appears that a slope in the water surface of only 0·383 inches a mile would give a mean velocity of 4 miles an hour; and one of 0·923 inches, a mean velocity of 5 miles. The Mississippi along a straight portion at Carrollton, during high water, when the *maximum* depth was 136 feet and the slope but 1·3 inches, has a mean velocity of 4 miles per hour. (See beyond.)

Making allowance for the probable amount of resistance from the sources above mentioned, it would seem that a slope of 2 inches a mile to Springfield would have been sufficient to meet the conditions; and that one of 3 inches would have been too great. But suppose it 3 inches a mile; a change in the pitch of the valley amounting to 18 inches a mile would have been needed to produce it. If we suppose it 6 inches—which is a very large pitch in any stream under continuous flow (that is, not broken into parts by dams) which was the fact with the flooded Connecticut down to Middletown—the needed diminution in the pitch of the valley would have been 15 inches a mile. This amount, 15 inches, added to the 15 inches a mile deduced from the elevated sea-beaches, would make for the total diminution in mean rate of pitch to Springfield $2\frac{1}{2}$ feet a mile: and if the amount were 18 inches, the total would be $2\frac{3}{4}$ feet a mile, which would make the change at Haverhill hardly 50 feet less than at Montreal.

The later change, whatever its amount, would have been a continuation of the former. Whether it was confined or not to the Connecticut valley—a line of weakness in former geological eras—must be determined by the study of other valleys to the east and west, especially the Merrimack on one side and that of Lake Champlain and the Hudson on the other. It is a strange fact that the terrace formation of the southern part of the Lake Champlain region, and of its continuation along Lake George to Albany on the Hudson has not yet been carefully studied.

In view of so great changes in the slope, reining in the waters, the floods of the Connecticut Valley lose something of the magnificence portrayed in the high terraces. But, on the other hand, the conditions are brought within more reasonable, or less improbable, limits.

It is interesting and instructive to compare, in this connection, the velocity and other elements of a straight portion of the Mississippi River at high water. According to the measurements of such a portion of the river in the vicinity of Carrollton,* referred to above, made by the Delta Survey in 1851 under the special charge of Professor C. G. Forshey, and published on page 316 of

* Carrollton is 121 miles from the mouth of the Mississippi, and at high water the surface of the river is 15·2 feet above sea-level.

the report of Humphreys and Abbot as one of the thirty cases upon which data their formula for velocity was based, the elements were as follows:

Area of cross-section in square feet.	Width in feet.	Wetted perimeter in feet.	Maximum depth in feet.	Mean velocity per second.	Slope.
193,968	2653	2693	136	5·9288	0·00002051

The *calculated* velocity found by the formula was 5·9673 per second, giving a difference of 0·0385 feet. The velocity obtained is almost exactly four miles an hour; and the slope to which this velocity corresponds is, as already stated, 1·3 inches per mile.

By means of the formula, we have, from the same conditions in the Mississippi as to dimensions, but with other assumed slopes, the following results:

Slope per mile in feet.	Slope per foot.	Velocity in miles per hour.	Velocity in feet per second.
1·75	0·0003314	8·129	11·918
3·0	0·0005682	9·32	13·670
4·5	0·0008523	10·32	15·145
6·0	0·0011364	12·47	18·292

The case of the Mississippi differs from that of the flooded Connecticut in the less average depth—the *maximum* being 136 feet. The Mississippi River was more like the New England stream when it was itself flooded from the same cause; when its læss deposits were formed, according to Professor E. W. Hilgard, not many miles above the head of the delta, to a height of 450 feet above the sea. Its average width below the mouth of the Ohio exceeded 50 miles. Professor Hilgard points out the fact* that the "Grand Gulf Group," of the border of the Gulf of Mexico, along, and east and west of, Louisiana, (representing the Tertiary after the Eocene,) is capped near the gulf by beds of stratified drift to a height of 500 feet above the gulf; and that the facts indicate that an elevation of the gulf border, and of that portion of the Mississippi valley, was begun in the early Tertiary and went on until it had reached a height in the Glacial era of 900 feet, after which there was a reverse movement. In that reverse movement (or after it and a new bend upward), the region must have been long at or near 450 above the sea (if there was not, in place of part of it, a diminution of pitch northward), in order that the slope of the water-surface of the river should have been reduced to a minimum, so as to allow of such fine deposits as the læss.

On this view, the Mississippi had a dam, and was put thereby into a lacustrine condition, right for making læss or loamy deposits. The Connecticut had a dam also; but it continued nevertheless to be a river throughout, its loamy deposits and clay-beds being subordinate in the upper terraces to its sand-beds and those of coarser constitution.

* In this Journal, xxii. 58, 1881.

[To be continued.]

ART. XVIII.—*On the Geographical Distribution of certain Fresh-water Mollusks of North America, and the probable causes of their Variation*; by A. G. WETHERBY, Professor of Geology and Zoology, University of Cincinnati.*

HAVING set forth, in the first part of this paper, the main facts connected with the distribution of the *Unionidæ* and *Strepomatidæ*,† over the region under consideration, it now becomes my task to attempt a solution of some of the problems thereby indicated; for, to the careful student of this subject, several of its features are in the nature of unanswered questions; and these, it seems to me, will be found to be so intimately associated with the history of our continent's development, and especially with that part relating to the evolution of its systems of drainage, as to cause continual reference to that subject, in the light of present geological knowledge.

Without stopping, at this point, to discuss the zoological relationships which possibly indicate the marine ancestry of the mollusks under consideration, it is a fair presumption that *the first fresh-water forms were lacustrine.*

Of the truth of this proposition there seems to be ample evidence in the fact, that, even during Archæan times, fresh-water lakes were not impossibilities or even improbabilities. The processes by which salt water areas, isolated from the main ocean, pass through their various stages of approach to fresh-water conditions, are familiar to all students of physical geography; nor is the fact of the existence of such bodies of water in areas of limited drainage any less well known. High plateaus and low plains alike contribute examples of this fact. They are most typical in regions of comparative aridity from various causes; and many such bodies of water now known have been undergoing the freshening process since the early Tertiaries.

It can not, I think, be doubted that there have been, throughout the geological ages, depressions of this description; and when we consider the fossil shells found in lacustrine deposits, and the forms now inhabiting such bodies of water as Lake Baikal and Lake Balkash, the probability of their gradual differentiation from marine types, and of their successive variations as fresh-water forms, seems to be associated with no factor of the improbable.

In this consideration due weight must be given to the great

* From the Journal of the Cincinnati Society of Natural History, July, 1881; being Part ii of an article of which Part i appeared in January, and was noticed on p. 76 of this volume.

† The Strepomatidæ comprise the American species formerly referred to the Melania family.

influence of Archæan lands upon the subsequent moulding and forming of the continent, whose final systems of drainage, and all the stages of development leading to them, were determined by this early and stable region, which had its representative areas on both sides of the incipient uplift, and at comparatively isolated points over the great central basin; areas around which clustered, throughout the history of continental progress, the geological activities that determined everything.

It seems desirable, in discussing the variations above hinted at, to remember that there must have been a far greater impetus given them, when changes in drainage brought to these creatures the vicissitudes accompanying distribution into bodies of flowing water. Such changes of station, and finally of habitat, were among the last possibilities of continental growth, because it was only in connection with the later grand movements associated with terrestrial evolution, that present systems of drainage became possibilities. It is likewise true, that at no time since any drainage has existed on the continent in streams large enough to contain a shell fauna, has there been such a complication of circumstances favorable to the local variation of that fauna, and the consequent establishment of varieties as now. For while it is a well determined fact in geology, that, with the progress of continental evolution, the complexity of the characters of strata increased, it is also true that each of these new features would become a factor of importance in modifying the character of streams flowing through the land, and would, for this reason, aid in changing the nature of the mollusks inhabiting them. And these conditions reach their greatest development in mountain regions, for the following among other causes that may be enumerated.

First, it is in such areas that streams cut their way through strata of the most heterogeneous character, partly owing to the effects of metamorphism and other disturbing causes upon strata that may have been, originally, more homogeneous. *Second*, because even where metamorphic effects may be wanting, the range of formations traversed will be greater through the more extensive erosion. *Third*, because in mountainous regions there is an increase of probability that mineral deposits will fall in the path of streams, which will effect changes in the water, causing abnormal stunting, or extraordinary development, of given forms. *Fourth*, because the influx of side streams, bearing the water of mineral springs, will add to these effects. *Fifth*, because here we have the maximum of extremes in rate of current, and consequently the maximum of capacity to transport sediments that may act favorably or unfavorably upon the various creatures inhabiting these streams. *Sixth*, because of the probability that these mollusks have been propagated down stream, to the limit of favorable conditions—a

limit always determined in the first place by geological causes —and because of the variation in the conditions met in this traverse. *Seventh*, because combined with these circumstances is the fact, that all the stages in the development of these creatures are passed in an element thus unstable, amid conditions thus diversified, where the slightest tendency to variation must have the maximum of exciting causes constantly operating to call it into play. If, then, it be admitted that there is in the animal races any tendency to variation, and any capacity for adaptation, life, under such circumstances, would be a continuous development and exercise of these inherent qualities. For mountain regions have been the seat of origin of all drainage, and, no doubt, of the first forms of life inhabiting that drainage.

Now let us examine these probabilities in the light of the actual facts connected with the distribution of certain fresh-water shells.

First, we may consider the circumpolar distribution of the *Limnæidæ*. These mollusks are essentially *lacustrine*, for while they are distributed into rivers and smaller streams to some extent, their station of fullest development is in lakes, the world over.

The genera, *Physa*, *Limnæa* and *Planorbis*, are essentially northern forms, for it is in the cooler regions of the earth that they reach their largest size and greatest differentiation. Distribution southward is accompanied by a stunting of forms in all cases but that of the sub-genus *Bulimus*, of which the *B. aurantium* passes through the American tropics, and is many times the size of its circumpolar northern relative, the well-known *B. hypnorum*. This case stands as the only exception to an otherwise universal rule, respecting a group of mollusks covering many described species, and yet one in which the differentiation of forms has led to such interminable varieties, that the most critically accurate of our conchologists hesitate to label them. The careful student of our North American forms will find these shells more closely allied to their European relatives than any other group of mollusks found on the two continents, unless it be the *Succininæ*, and a few littoral marine species; and, as it is not possible to separate them *inter se*, upon anatomical distinctions, in the greater number of cases, it may be regarded as a substantial proof of their high antiquity when taken in consideration with the following facts: first, their universal presence in the lakes of the older geological formations at the north; second, their circumpolar distribution; third, their presence in regions unfavorable to the development of other families of mollusks, as testified by their absence; fourth, their persistent appearance together, even southward.

over regions of elevation. For these reasons, and for others of convenience in this discussion, I shall designate them as Fauna A, and will add this important and distinctly proven statement: that they reach, on our continent, their maximum of size, of differentiation, and the greatest local number of so-called species, in precisely that portion of it having the greater number of lakes, in regions of the oldest land or contiguous to it, and where there is the greatest paucity of other mollusks. This fauna is thus clearly shown to be regional, and the inference is fair that it has a very high antiquity.

Over the same region, both in Europe and America, we have distributed a few species of the *Unionidæ*, mostly represented by the genus *Anodonta*, a lacustrine group, always affecting still waters with muddy bottoms. These forms, with plain surface, and comparatively thin shells, are the predominant types of the Unionidæ over the whole northern portion of our continent from Maine to Oregon. It is among the species of this genus that there occurs the greatest apparent synonymy, and the systematic zoologist will find himself, in the study of these shells, face to face with the question of varieties in endless and interminable confusion. Nor is this statement an exaggeration, when we remember that European malacologists, of greater or less repute, have made nearly one hundred synonyms for the *A. cygnea* alone; and that the slightest review of our North American species, in the light of the evidence offered by geographical varieties, now well known, must reduce the number of so-called species more than one half; and many of these varieties continue from Eastern New York to Minnesota, and a fewer number, southward to the very borders of Mexico, *over all of which area I have traced them!* These shells, for like reasons with the first, I shall designate as Fauna B.

The region occupied by A and B contains very few representatives of the *Strepomatidæ*, or Fauna C. Their geographical range northward was set forth in the first of these papers; and it is a significant fact that the few species of the *Strepomatidæ*, occupying this region, are those belonging to types that farther south, where the conditions of variation enumerated in another part of this paper reach their maximum, are so intimately united by varieties as to render their separation into distinct species, in most cases, utterly impossible; as the shells from different localities are so completely blended, that it is no exaggeration to say that fifty per cent of the described species are the merest synonyms. At the north, even, the difficulty begins; and it vastly increases in the more southerly mountainous region. This fauna differs essentially from A and B, in that it is not, normally, lacustrine, but fluviatile. A very few species are found in lakes, occasionally; but there is in these

shells an inherent aversion to still water, which characterizes all the genera, leading them to frequent rather the rapid parts of rocky streams; and here it is that we meet their greatest diversity of types, and the greatest variety of coloration and ornamentation. This peculiarity of station is so persistent, that no skilled collector ever searches for them in level reaches of deep water, unless in the case of a few species of *Pleurocera*, which affect such localities; but *Io*, *Angitrema*, *Lithasia*, *Anculosa*, *Schizostoma*, *Goniobasis*, and *Strephobasis*, all genera represented by an infinity of varietal forms, seek always clean, rapidly flowing water, in rocky or gravely river beds; and these groups are only represented by the genus *Melanopsis*, over the same range in Europe and Asia, and by *Goniobasis* and *Pleurocera* at the north, in America, their grand metropolis; in foreign lands their representatives, also, are confined to a range mostly south of that occupied by A and B. This fauna has a very limited distribution of genera and species west of the Mississippi, a fact easily traced, I think, to true geological causes, some of which are past, and others are now in operation.

The shells designated as Ohio River Types in my previous article, I shall call Fauna D. Of its geographical distribution, varieties, and persistent forms, enough was said in that paper; and since it was written, I have received, from the very southwestern borders of Texas, a collection of Uniones gathered at random, which contains nothing but absolutely typical Ohio River species. South of the Ohio, in parallel streams, beginning with Kentucky River and Green River, and continuing to the eastern and southeastern tributaries of the Tennessee, we find, as has already been stated, a group of shells of a distinct facies, requiring no expert knowledge of conchology to enable one to see that it differs, as a whole, from the Fauna D, with which it is associated. Its southern distribution is coëxtensive with that of Fauna C, in all the larger and many of the smaller streams. Here occurs the greater number of described "species" of the genus *Unio;* for among the forms filched from these prolific streams, malacological enthusiasts have disported themselves as species-makers, until the crying need of our times is an honest, impartial, and thorough review of the whole subject. The approximate boundaries of Fauna E may be placed between the Ohio River on the north, the Tennessee on the south, the Appalachians and the Mississippi. One fact is of curious import here; and it deserves to be put upon record in this discussion, and in this place. In his last edition of his Synopsis of the Family Unionidæ, 1870, which he tells us is his "most important work," Mr. Lea makes the following remarkable statement, the truth of which he had abundant opportunities to verify: "although I have examined critically,

and published descriptions of the soft parts of 254 species of this family, and have often dissected 50 to 100 of the same species, I can not see, as yet, any useful division that could satisfy the student or the adept, which can be made by systematic difference in the organic forms of the soft parts." This means, I suppose, that the differences of the soft parts are so small as to afford no safe basis upon which to predicate classification. I may add to this, that the most intimate study of the anatomy of different species of the *Limnæidæ* and *Strepomatidæ*, has convinced me beyond reasonable doubt, that specific differences, supposed to be indicated in the shells, do not extend to the animals themselves, so far as these studies go to show. I have now in course of preparation a memoir on this subject, which I hope soon to publish with accurate anatomical illustrations. Here is one of those strange facts, standing at the very threshold of the question of evolution, which finds a parallel in the *Lingula* and the *Rhizopod*.

We may now venture upon a few suggestions, to which these considerations give rise. Clearly the oldest shell fauna upon the continent would have naturally inhabited Archæan regions: and as it is altogether likely, from chemical facts associated with the deposit of iron ores, and the presence of graphite in the older rocks of the continent, as pointed out by Dr. Hunt and Dr. Dawson, that organic life may have existed to an extent not yet determined by fossils actually discovered as such, I think we do not pass beyond the bounds of probability in assigning to Fauna A a very remote antiquity. From its original *locus*, it has spread to the limit of suitable conditions, a limit undergoing constant variations, perhaps, through the geological ages, but which has been determined by boundaries mainly fixed by true geological causes. Through adaptation this fauna has, in a few cases, overstepped its primitive barriers, but it remains, as we have seen, true to its original instincts in all its more important phases. It is not probable, as may be suggested by the doubting reader, that this fauna would have been exterminated by the great glacier, which is supposed to have originated in its peculiar haunts, but more likely that the few species having an abnormal southern or southwestern range, received the first impulse of distribution in that direction from the glacial condition; and that, with the northward retreat of the glacier, they simply resumed their normal habitat, continuing their distribution in that direction, in succeeding times, to the northern lakes of British America. In studying Fauna B, we find evidence that a previous distribution, probably severed by the same or other causes, has never been fully united in a few cases—as in that of the *M. margaritifera*, occurring in Maine and Oregon, but not between these stations so far as now

known. But in most cases, the re-union has been complete. Such remnants as the Glacial epoch left, have been equal to the emergency of perpetuating their races over the region desolated by glacial action, and they may thus indicate what are the possibilities of development under determinate conditions. It may be suggested, that as the species of so-called *Strepomatidæ* of the west coast have rather the facies of the tropical Melanians, and as the other associates of the *M. margaritifera* in the waters of Oregon are species not elsewhere found, that this little faunal remnant is an independent one, and I readily agree to all this; yet there is no doubt of the existence of a Fauna B, or of its distribution, and the possibility that its present species are the descendants of a geological remnant like those of A. Still more striking is the evidence to be adduced from Fauna C. The region over which this group is distributed may have had some drainage, though perhaps slight, as far back as the epoch of the Cincinnati uplift. It thus may have continued through all the Paleozoic ages thereafter. What wonder, then, that we have here such diversity of forms, when we remember the mutations through which the continent subsequently passed to the termination of the Paleozoic. Local elevations and submergencies, and the various phenomena associated with the progress of continental development, brought to these creatures a series of vicissitudes that may have left many remnants in favored spots, whose descendants, modified and changed as they are, afford us the multitudinous varieties which this fauna assumes throughout its metropolis.

Indeed, if we could reach the ancestral form of these creatures, we should have another proof of the existence of what have been so philosophically called "comprehensive types;" and it is by no means a difficult thing to show abundant evidences of their presence in this heterogeneous host of their modified descendants, as I hope to point out hereafter. Even if this fauna does not antedate the Carboniferous epoch, the station which it has always occupied, for reasons already shown, would have brought a maximum of differentiating causes to bear. Nothing seems clearer to me than the separate origin of D and E. This is indicated by the merest superficial study of the shells, and I confidently expect that future geological explorations, among the western Tertiaries, may bring to light additional evidence upon this subject; and that when the habits and anatomy of these animals have been more thoroughly studied, and when we have a fuller understanding of the relations existing between the living and the fossil species of western Europe, and the fossil Tertiary species of southeastern Europe, new light will begin to break in upon the "origin of species" among these protean bivalves; for such work is the

special province of geology, and the highest generalization to which the perfection of geological knowledge can lead us.

In considering the facts connected with the exploration of the western lake basins, we find the *Unionidæ* to be distributed through the whole series of deposits from the Jurassic to the Tertiary, and well through the latter. In a very philosophical discussion of this subject, Dr. White has shown that there is an intermingling of forms, and an extent of differentiation pointing to remoter origin. But he has, in a foot-note on page 620, made the following statement which needs correction. "It is a significant fact that those North American rivers which contain the richest Unione fauna drain Mesozoic and Tertiary regions, while those that drain Paleozoic and Azoic regions have a comparatively meagre Unione fauna." The whole drainage of the Ohio is Paleozoic, or so nearly so that we may call it such. This stream and its tributaries south and southeast are the metropolis of these shells. And it is here that we find the two faunas above indicated most distinctly developed. The rivers draining the Mesozoic and Tertiary regions of the west have a very meagre fauna, both as to species and individuals; and I have already stated, that, with the exception of the few *Anodontas* of the northwest, the entire assemblage is composed of Ohio types. Until series of casts of the Ohio River shells are made, and these are carefully compared with the casts of species described from these western localities, we shall not have reached the best conclusion which a study of these fossils will afford us. If we consider the species of the Mesozoic and Tertiary regions of the south and southwest, we shall find that when we have removed the Ohio types from the lists, very few valid species remain. How absolutely true this is, and how great is the synonymy of these shells, I am sure is not the well understood fact in American malacology that it ought to be. There can be little doubt that the distinctively Ohio types, thus widely distributed, and so greatly differentiated, antedated any other forms occupying the same region with them. But other groups, during the mutations of the geological ages, left their remnants which have spread over the same area. The persistent species have either less tendency to variation, or the precise circumstances to call out such latent energies have not yet been brought into active account; while other forms, for opposite reasons, present us an infinity of varieties, always easily recognized, and of the derivative character of which no person, who has investigated this subject, can have any doubt.

In this connection the isolated fauna of the Coosa, to which reference was made in the previous article, must not be neglected. This stream flows through a comparatively limited drainage. It contains two genera, *Schizostoma* and *Tuiotoma*,

represented by thirty species, that have not yet been found outside of it; and this in a region where every stream contains an abundance of *Strepomatidæ*. How easy for a slight geological disturbance to obliterate the record of their existence: how easy to have an isolated remnant of this unique fauna left in the upper reaches of this mountain stream, when a less submergence than took place in this region during the Tertiary, would exterminate many contemporary species in the lower part of its drainage. In such a case, this isolated remnant, unique and strange, would present us with a problem for consideration like that of the *Unio spinosus*. This single example well represents the principle to which this article points, and shows how readily, in earlier times, when systems of drainage were comparatively limited, and opportunities for the spread of species were correspondingly less, there might have been many cases like that of the Coosa, during the various epochs, which left remnants of their shell-fauna: and those remnants, which had less tendency to variability, have persisted with comparatively little change; or, possibly, the changes have been in a direction which did not characterize other groups with which they were associated, leaving them distinct. At all events, the faunas are plainly indicated, and in many cases it is not difficult to point out central forms, around which they seem to be clustered.

The various other genera of Fresh-water Shells, found in the western deposits above mentioned, all exhibit a tendency to varieties equal to that of the *Unionidæ*. The species of *Goniobasis* (?), *Viviparus*, *Physa* and *Planorbis*, are all cases in point; but one can not help seeing how closely the three genera last mentioned are related in all these fossil forms to species now living; and it seems that Dr. White's remark, accompanying the description of the *Anodonta propatoris*, "It is not to be denied that its separate specific identity is assumed from its known antiquity, rather than proved by its structure and form," might have been, with still greater significance, written of many of these fossil *Viviparidæ* and *Limnæidæ*. Let this be as it may, I am convinced that the origin of these Tertiary and Cretaceous forms is to be sought in a Paleozoic progenitor, whose probable starting point was in regions adjacent to the western Archæan. While the species of fresh-water habitat may have persisted since the Carboniferous, in all the region between the Appalachians and the Mississippi, much of that portion of geological time has been fatal to such existence in the region west of the same stream; and though Mr. Tryon speaks of the Mississippi as a barrier to the westward distribution of species, it seems to me that the cause is really to be found in the character of the western tributaries as well; for while the

muddy waters of the Mississippi are an effectual barrier, in a general way, accidental transportation, or a few cases of actual traverse, that we cannot doubt must have taken place, would have furnished abundant types for spreading the species through our western rivers, if the conditions had been favorable; but they were not favorable, and consequently no such distribution has taken place. Hence it is, that the few species of shells inhabiting those streams, seem to me more likely to be the descendants of an ancestry of old date, and their general correspondence in form to the Ohio type, points to their community of origin. The Fauna E is here wanting; nor has it any representative. When we come to the consideration of the down-stream distribution of the species east of the Mississippi, we find the *Strepomatidæ*, as represented by their most characteristic genera, and Fauna E of the *Unionidæ*, to have a barrier in that direction. Here they cease, and beyond it, in the Tennessee, Cumberland, etc., we find mainly the Fauna D. Since this fact is general, it becomes one of high significance in this discussion, and stands as a unique evidence in favor of some of the suggestions here made; and it shows conclusively, that continuous water is not the only condition of molluscan distribution; and that the present station of *Io*, *Goniobasis*, *Anculosa*, etc., in mountain streams, and in the more rapid portions of these streams, is the result of the presence of conditions to which these creatures are by nature fitted; and while a few species are more cosmopolitan, owing to their greater capacity for adaptation, or to their remote ancestry, the great bulk of Fauna C has its range circumscribed as has here been indicated.

While the evidences upon which the theory of this discussion rests, from the geological and phylogenic aspects of the case, have been thus hurriedly cited, there is yet another argument, resting mainly upon an anatomical basis, which, as above indicated, I hope, after a while to bring out. So little is known of the close relations of these animals from this point of view, that I am of the opinion that the systematic zoologist will look with wonder and surprise upon the almost entire absence of structural unlikeness in animals, even in such matters as the distribution of the alimentary and circulatory vessels, that may be associated with the widest variation in the character of the shell. Nevertheless, there are cases in both these families, of structural differences as striking as the other facts which have led to this division of our shells into these highly characteristic geological groups; and to these evidences I shall direct attention in a future article.

ART. XIX.—*Description of a New Genus of the Order Eurypterida from the Utica Slate;* by C. D. WALCOTT.

IN the February number of this Journal,* notice was given of the discovery of the fragmentary remains of a large Pœcilopod in the Utica slate and its identification with the Eurypterida, a provisional reference being made to the genus *Eurypterus*. A review of this and the genera of its order shows that none of them present the characters seen in the remarkable cephalic appendage from which the genus now proposed derives its name.

Echinognathus, n. g.

Endognathary limbs (one or more pairs) formed of eight or nine joints, six of which carry long, backward curving spines articulated to their posterior side. Terminal joint slender, elongate, acuminate. Surface of the body and larger joints of the cephalic appendage ornamented with scale-like markings, as in the genus *Pterygotus*. Type, *E. Clevelandi*.

Echinognathus Clevelandi.

Syn. *Eurypterus? Clevelandi* Walcott. This Journal, vol. xxiii, p. 151, 1882.

The only portion of the body discovered is illustrated by fig. 1. It appears to be the left side or half of the ventral surface of the anterior thoracic segment. The reference to the ventral surface is from the presence of a thin membranous

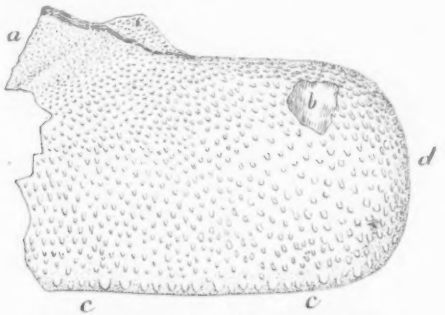


Fig. 1.—Reduced to 7-10ths the natural size.

extension of the anterior margin, a feature observed on the anterior segment of *Dolichopterus macrocheirus* Hall.† The test appears to have been thin and firm, and the margins are clearly outlined on the dark, smooth slate, while the surface is ornamented with fine scale-like markings on the anterior portion that increase in size toward the posterior margin (*c c*).

* Vol. xxiii, p. 151, 1882. † Pal. New York, iii, p. 414*.

Figure 2, is a sketch, 7-10ths of the natural size, of the cephalic appendage as it appears on the surface of the slate and in the matrix. The entire length of the appendage from the point *a a* to the end of the terminal joint 7, as restored to its natural position, would be 12·5^{cm}, exclusive of the basal joint at *a a*. The long spines of the joints 3 and 4 are 5^{cm} in length.

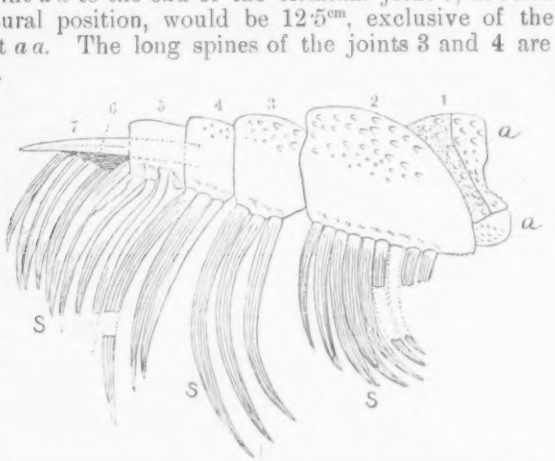


Fig. 2.—Reduced to 7-10ths the natural size. The joint (1) overlaps (2) and is broken away on its posterior margin. The line crossing it should be a slight ridge.

The joint marked (1) is broad and short with a rounded depression at the center of its inner margin. There is no evidence of the attachment of the long spines that are articulated to the posterior side of the succeeding joints. From the form of the joint and the presence of broken fragments of the test in the matrix at *a a* it is probable that it is the second joint of the appendage and that the first or basal joint is broken up. The joint (2) is large, elongate, rudely subtriangular, the long anterior margin curving around to meet the nearly straight posterior margin at its inner end. The latter margin has nine long curved spines articulated to it while the three following joints (3, 4) and (5) have but three each on their posterior margins. These joints (3, 4, 5), are more or less quadrangular in outline, (3) and (4) being transverse and (5) a little elongate. The spines of (3) and (4) are the longest of any attached to the appendage. Beyond (5) traces of another joint are shown (6), and another is indicated by the position o the three curved spines beyond those of (6). These two latter joints were crushed by the forcing back of the long terminal joint (7), the inner end of which is seen beneath the center of the joint (4). This joint or terminal spine is slender, slightly curved backward, and marked by a slight median ridge and longitudinal striæ. The surface of the

joint (1) and the anterior portions of (2) and (3) show the scale-like markings observed on the fragment of the thoracic segment. If there were but one joint beyond the transverse joint (1), i. e. the basal, the entire appendage would have had nine joints, if our interpretation of the crushed joints is correct.

The long curved spines (*s*, *s*, *s*), are a very curious feature of the appendage and the most marked character of the genus and species. They are articulated to the posterior margin of the joints, as the latter rest flattened out in the slate or shale, and there is no evidence but that they formed a single series, as shown in the specimen and in the drawing, fig. 2. Each spine is constricted a little near its base, forming a rounded end or point of articulation; from this well out toward their pointed termination they retain an average width curving gently backward and inward. They appear to have been flattened when in a natural condition, and formed of a thin test which is rather strongly striated.

It is difficult to understand the purpose these spines served unless they are considered as having some relation to the branchial system of the animal. That they were used in securing food or carrying it to the mouth is not apparent, and no other use than the above is suggested from a study of the specimens we now have.

In the specimen of *Dolichopterus macrocheirus*, previously referred to, a few short, small spines are seen projecting from the posterior margins of the third, fourth and fifth joints of the third endognath. That they may represent in a greatly modified degree the spines shown in fig. 2 is not improbable. *Eurypterus punctatus* (Salter) Woodward, as restored in Woodward's Monograph of the Fossil Merostomata, p. 157, has a pair of long curved spines on four of the joints of the endognathary palpus, but they are represented as projecting forward, which does not appear to have been the case in the Utica slate species.

The character of the endognathary palpus of *E. Clevelandi* may indicate the approach to an earlier type of the Eurypterida, but from the characters shown by these remains and the fact that its size, estimating from the fragment of the thorax, was not less than 45 or 50^{cm} in length, and the approximate width 15^{cm} or more, it is evident that we must search deep in the strata of the Trenton group, or even lower, for the first members of the order.

As far as known to us the Eurypterida has not been represented hitherto on the American continent below the Medina sandstone of New York, and no described species is known below this horizon elsewhere. M. Barrande mentions the discovery of a fragment of the test of a Pterygotus in his étage D, 5,

at the close of the second fauna,* which would place it a little below that of the Medina sandstone.

The specific name of the species under consideration was given in honor of Rev. Wm. N. Cleveland, who obtained the specimens described in the Utica slate formation north of the village of Holland Patent, Oneida County, N. Y. On the same pieces of slate with them occur two characteristic fossils of the formation, *Leptobolus insignis* and *Triarthrus Becki*, and I have also obtained from the same locality and stratum of slate, *Dendrograptus tenuiramosus*, *Climacograptus bicornis*, *Schizocrania filosa*, *Endoceras proteiforme*, etc.

Several collectors have been and are now working in the Utica slate both in New York State and Canada, and a number of undescribed and interesting species are in their hands, as also several described from the Trenton limestone but unknown from the slate before. It is largely due to the persistent efforts of Mr. Chas. H. Haskell that the many localities in Oneida County, N. Y., have been discovered, and their rich fauna made known from the slate, from one of which localities the form we have described was obtained.

ART. XX.—*Notice of the remarkable Marine Fauna occupying the outer banks off the Southern coast of New England, No. 4*; by A. E. VERRILL. (Brief Contributions to Zoology from the Museum of Yale College: No. L.)

ECHINODERMATA (*continued*).

In the following list there are included 48 species. Of these, 22 have not, hitherto, occurred elsewhere on our coast; 26 have been found farther north, in the Gulf of Maine, or off the coast of Nova Scotia, and may be considered as arctic; at least 22 are European, and of these 18 or more are northern European; at least 14, and probably more, have been taken in deep water, in the Gulf of Mexico, or off Florida, by Pourtales and A. Agassiz, but there is, as yet, no general lists of their starfishes and ophiurans: of the whole number, only six are, so far as known, peculiar to this district, and probably this number will soon be reduced. Many of the species have a very extensive range, on both sides of the Atlantic, and also a great range in depth, occurring in much deeper water than was found at any of our stations. Species dredged only in less than 60 fathoms are not included.

In the list, the range of depth given applies only to this special region, as determined by the stations here included.

*Système Silurien Centre de la Bohême. I, supl. pp. 556, 557. 1872.

List of Echinodermata.

Holothurioidea.

THYONE SCABRA Verrill. 51–435 fathoms.

Stations 870, 871, 876, 877, 894: 919, 939, 943, 949, 1038: 1040, 1049.

TOXODORA FERRUGINEA V., sp. nov. 100–155 fathoms.

S. 870, 871, 873, 876, 877: 943, 949.

MOLPADIA TURGIDA Verrill. 120–182 fathoms.

S. 876 (1): 1026 (2).

Echinoidea.

SCHIZASTER FRAGILIS (Dubeu & Koren) L. Agassiz. 64–258 fathoms.

S. 865, 869, 870, 871, 873, 874, 876, ab., 877, ab.: 939–941, 943, 945, 950, 1025, ab., 1026, 1032, ab., 1035, 1036, 1038, ab., 1045.

SCHIZASTER CANALIFERUS L. Agassiz (variety ?). 65–130 fathoms.

S. 871, 873, 874, 876, 877: 921–922 (9), 940, 941, 949.

BRISSOPSIS LYRIFERA (Forbes) L. Agassiz. 65–146 fathoms.

S. 870: 921, 1038. Europe and W. Indies.

SPATANGUS PURPUREUS Leske. 130 fathoms.

S. 940 (1 large, living). Europe and W. Indies.

ECHINOCYAMUS PUSILLUS (Müller) Gray. 146 fathoms.

S. 1038 (1). Europe and W. Indies.

ECHINARACHNIUS PARMA Gray. 10–219 fathoms.

S. 951, 985–989, very ab., 1038, many.

PHORMOSOMA SIGSBEI A. Agassiz. 458 fathoms.

S. 1029 (1 living). W. Indies (A. Ag.)

ECHINUS GRACILIS A. Agassiz. 86–146 fathoms.

S. 872 (2): 940 (7), 1038, 1039: 1046 off Delaware Bay, 3 large.

ECHINUS WALLISI A. Agassiz. (=*E. Norvegicus* in list of 1880). 258–458 fath.

S. 893, 894: 939, 1028, 1029.

TEMNECHINUS MACULATUS A. Agassiz. 115 fathoms.

S. 871. Gulf of Mexico (A. Ag.)

DOROCIDARIS PAPILLATA A. Agassiz (variety). 104–146 fathoms.

S. 1038 (1): 1046 off Delaware Bay (5).

Asterioidea.

ASTERIAS VULGARIS (Stimpson) Verrill. Shore to 208 fathoms (? 368).

S. 869: 917-920 ?, 994 (3), 1032 (1), 1035 (12), 1037 (12): 1046 (1), 1047: ab. in shallower water.

ASTERIAS TANNERI Verrill. 69–192 fathoms

S. 869–872: 922, ab., 923, ab., 940, 941, ab., 949, 950, 1035: 1047, ab.

STEPHANASTERIAS ALBULA (Stimpson) Verrill. 64–130 fathoms (? 192).

S. 865–867, ab., ? 869, 870–872: 921–923, 940, 949–950, ab., 1035, ab., 1036, very ab.: 1043, ab., 1046, 1047.

CRIBRELLA SANGUINOLENTA (Müller) Lütken. Shore to 115 fathoms.

S. 865–867, 871, 872: 949—commoner and larger, in shallower water, nearer the coast, S. 928, 933, 934, 956, 957, 985–987, 1009, 1036.

DIPLOPTERASTER MULTIPES (Sars) Verrill. 130–212 fathoms.

S. 869, 878, 895: 924, 925, 938, 939 (13), 940 (10), 945 (11), 947, 951, very large, 1025, 1026, 1032 (22), 1033, 1038: 1047.

PORANIA GRANDIS Verrill. 69–192 fathoms.

S. 869, 872: 923, 940, sev., 949, 950, sev., 1039: 1046 (9 j.)

PORANIA SPINULOSA Verrill. 192–368 fathoms.

S. 869, 879, 894, 895: 925, 938, 939, 945, 946 (10), 951, 998, 994, 1025, 1032.

PORANIA BOREALIS Verrill. (= ASTERINA BOREALIS V.). 192–225 fathoms.

S. 869, 879.

ODONTASTER HISPIDUS Verrill. 64–487 fathoms.

S. 865, 868, 869, ab., 871–873, 878, 879, 892, 894, 895, 921, 922, 940, ab., 946, 947, 949, 950, ab., 994: 1043, ? 1049 (1 j.).

ARCHASTER FLOKÆ Verrill. 100–410 fathoms.

S. 869, 873, 879, 881, 895: 924, 925, 938–940, 943, 945, 946, 951, 997, ab., 1025, ab., 1026, 1028, 1032, 1033, 1038.

ARCHASTER AMERICANUS Verrill. 64–225 fathoms; ab. in 64–150.

S. 865–868, very ab., 871, ab., 873–876, very ab., 877, 879: 918, ab., 920–921, very ab., 940–941, very ab., 945, 949, 950, very ab., 1025, 1035–1037, very ab., 1038, 1040, 1043.

ARCHASTER AGASSIZII Verrill. 182–487 fathoms.

S. 879, 880, 881, 891–894, 895, 938, 939, 946, 947, ab., 952, 994, ab., 997, very ab., 998, 1025–1026, ab., 1028, 1029: 1049.

ARCHASTER PARELII Dub. & Koren. 225–487 fathoms; scarce.

S. 879, 892–894: 938, 939, 947, 952, 1028, 1 j., 1029: 1049 (6).

ARCHASTER TENUISPINUS Dub. & Koren. 368 fathoms. S. 994 (1).

ARCHASTER MIRABILIS (?) Perrier. 310 fathoms.

S. 938 (1). Gulf of Mexico (A. Ag.).

ARCHASTER ARCTICUS M. Sars. 183–310 fathoms.

S. 925, 938, 939, 946 (2), 951 (3), 1028, 1032, sev., 1033.

ARCHASTER BAIRDII Verrill, sp. nov. 388 fathoms. S. 952 (6).

LUIDIA ELEGANS Perrier. 51–192 fathoms.

S. 865–872, many large, 871 (17), 873, 876, 877: 919, 921–923, ab., 940–941, ab., 949, 950, 1035, 1036, 1038, 1047.

CTENODISCUS CRISPATUS Düben & Koren. 182–310 fathoms.

S. 879: 938, 939 (5), 1025, sev., 1026, 1032.

Ophiuroidea.

OPHIOGLYPHA SARSII Lyman. 30–368 fathoms (? 458).

S. 865–871, ab., 873, ab., 877, ab., 879, 895: 917, 918, very ab., 919, 924, ab. l., 925, 940, 943, 989–994, 991, ab., 1025, ab., 1026, very ab. l., ? 1029, 1032, 1033, ab. l., 1035, 1038: 1047.

OPHIOGLYPHA SIGNATA Verrill. 100–258 fathoms.

S. 869, 870 (10), 873, (24), 875, 877, 878: 939, 1038.

OPHIOGLYPHA (OPHIOPLEURA) AURANTIACA Verrill, sp. nov. 82–310 fathoms.

S. 869 (2), 872, 880 (2), 895 (4): 938, 939, 946 (6), 951.

OPHIOGLYPHA CONFRAGOSA Lyman. 238–506 fathoms.

S. 895 (1): 937 (1), 938 (2, large), 1028 (13), 1029.

OPHIOMUSIUM LYMANI W. Thomson. 238–500 fathoms.

S. 891 (11 j.), 892 (5), 895 (1), 994 (2).

OPHIACANTHA BIDENTATA Lyman=O. SPINULOSA M. & Tr. 192–202 fathoms.

S. 869: 945.

OPHIACANTHA MILLESPINA Verrill. 100–258 fathoms.

S. 869, ab., 870, 871, 873, 895: 924, 925, ab., 938, 939–940, ab., 945, 951, 1026, 1032–1033, ab., 1034, 1035, 1038, ab., 1039.

OPHIOPHOLIS ACULEATA Gray. Shore to 258 fathoms.

S. 865, 869, 871, 872, 879, 895: 920, 922, 924, 925, 939, 940, 943, 945–947, 949, 951, 986, 989, 1025, 1032, ab., 1033, 1035, 1036, 1038, very ab., 1039, ab.: 1043.

AMPHIURA OTTERI (?) Ljungmann. 192–500 fathoms.

S. 869, 880, 891, 895: 997, 998, 999.

AMPHIURA ELEGANS Norman, var. TENUISPINA Ljung. 120–487 fathoms.

S. 869, 871, 876, 892, 894, 895: 1038.

AMPHIURA MACILENTA Verrill, sp. nov. (?=*a. Abdita*, young). 51–115 fathoms.

S. 865, 871: 919, 920, very ab., 921, 941.

OPHIOCNIDA OLIVACEA Lyman. 64–142 fathoms.

S. 865, 869, 871, ab., 872, 873–877, ab., 878: 921, 940, 941, 949, ab., 1040, ab.

OPHIOSCOLEX GLACIALIS Müller & Troschel. 115–238 fathoms.

S. 869, ab., 870, 871, 879, 895: 924, 925, 939, 940, 945, ab., 946, 951, 1025, ab. 1026, 1032, 1033.

ASTROCHELE LYMANI Verrill. 258–458 fathoms.

S. 938, 939, 1028, ab., 1029, ab.

Crinoidea.

ANTEDON DENTATUM (Say) V.=ANTEDON SARSII (D. & K.). 85–258 fathoms.

S. 869–871, 873–876, 878–880, 895: 925, 939, ab., 940, 943–946, 949, 1025–1027, 1032, 1033, ab., 1035, 1038, very ab.: 1043, 1047.

The following species were taken by Lieut. Z. L. Tanner, in 1880, off Chesapeake Bay:

THYONE SCABRA V. S. 898.
SCHIZASTER FRAGILIS Ag.
ASTERIAS TANNERI V. 56 fath. S. 896.
ASTERIAS BRIAREUS V., sp. nov. 31 to 57 fath. S. 899; 900.
LEPTASTERIAS COMPTA V. 31 fath. S. 900.
DIPLOPTERASTER MULTIPES V. Two large specimens.
CRIBRELLA SANGUINOLENTA Lütk. 31 fath. S. 900.
ODONTASTER HISPIDUS V. 57 fath. S. 899.
ARCHASTER AMERICANUS V. 56 to 57 fath. S. 896, ab.; 899.
ARCHASTER AGASSIZII V. 300 fath. S. 898, ab.
OPHIOPHOLIS ACULEATA Gray. 31 to 57 fath. S. 899; 900.
AMPHIURA OTTERI (?) Lj. 300 fath. S. 898.
ANTEDON DENTATUM (Say) V. 157 fath. S. 897, ab.

Toxodora V., gen. nov.

Allied to *Chirodota*. Tentacles twelve, digitate. Skin thin, with scattered, slender, bow-shaped plates.

Toxodora ferruginea V., sp. nov.

Body cylindrical, elongated, very contractile, liable to rupture. Skin somewhat translucent, filled with minute, reddish brown pigment-cells, and having numerous, minute, slender plates, in the shape of a bow, or a parenthesis, with the ends incurved. Tentacles stout, with numerous digitations. Length, 50^{mm} or more; diameter, 8 to 10^{mm}.

Asterias Briareus V., sp. nov.

Arms variable in number; 10 in the largest example; long, slender; disk small. Radii as 1 : 9·5; lesser radius, 8^{mm}; greater, 76^{mm}. The rays have a strong dorsal ridge, and one lateral and a ventral one, on each side. Slender, transverse plates connect the dorsal and lateral ridges, leaving large spaces, in which are numerous papulæ, grouped in several clusters. Along the five ridges are long, slender, acute, rather distant spines; a few also stand on the cross plates; these spines are all similar and bear large, dense wreaths of small pedicellariæ near the base. Solitary pedicellariæ of large size and remarkable form are scattered between the spines, above and below; these are spatulate or hand-shaped, the wide tips terminating in five or six incurved claws, which interlock when the pedicellariæ are closed. Adambulacral spines slender, two to each plate, close to the ventral spines, with no intervening spines nor papulæ.

Ophioglypha Sarsii (Lütk.) Lyman.

Two varieties of this species occur, which differ widely. The larger and smoother form, without prominent disk-scales, is found exclusively in the deeper waters, while the form with prominent, swollen disk-scales is abundant in the shallower localities (40 to 60 fathoms), though often found, also, at greater depths; the latter is the form that occurs abundantly in the Bay of Fundy and off Nova Scotia, where it grows to a large size, without changing its character. The two forms also differ in other ways.

I have seen a few four-armed specimens. Peculiar color-varieties are common.

Ophioglypha signata Verrill, sp. nov.

Ophioglypha affinis Verrill, in former papers (*non* Lütken).

Disk varied in color, rounded-pentagonal, flattened above, or even concave when dried; covered with scales which form a distinct rosette; the dorsal surface is separated from the ventral by a marginal ridge, which becomes well-marked in dry specimens; notches, at the bases of the arms, slight, with an irregular and interrupted series of minute spinules; usually a short row

of small, slender spinules on each side of the notch, and a small, irregular, isolated group in the middle, sometimes nearly obsolete, or represented by only one or two small spinules, in the larger specimens; just below these there is a similar small group on the middle of the first visible arm-plate: the second arm-plate sometimes bears, also, two or more small spinules, but these never form a regular row. Disk-scales, when living, obscured more or less by a thin skin; the central scale and two alternating circles of five each, surrounding it, at a little distance, are round, darker colored and distinctly larger than those that intervene, which are small, but distinct, and often form rather regular circles around the larger scales: in the interbrachial spaces, near the edge, there are also larger scales: radial shields, irregular, long-triangular, their edges more or less covered by small scales, and separated by a rather wide wedge of small scales, in several rows. Oral plates, short shield-shaped, the breadth and length about equal; the outer and lateral edges form a regular curve, the inner edges make an obtuse angle. Mouth-papillæ, four on each side of each mouth-angle: the outer one is flat and broad, the others are slender, acute; the median papilla is larger, acute. The inner tentacle-pore is small and usually has a single small scale on each side; the others have one small scale. The arms are not very long, tapering to rather slender tips, with a median ridge. Ventral arm-plates widely separated, crescent shaped, wider than long, those near the base with a proximal angle. Upper arm-plates raised into a distinct median ridge, with a slightly prominent outer angle; those near the base are much shorter than broad, distally they become much longer than broad. Arm-spines three, rather slender and acute, the upper one is decidedly longer and larger than the next, its length equalling two arm-plates; the lowest is much the smallest. The genital slits have a row of very minute spinules along the upper half. The color is variable; the disk is usually prettily marked by a rosette of brown or dark gray spots on a paler ground, or the darker tint may take a star-shaped form, with five or with ten rays, with the radial shields usually pale; or there may be a combination of the rosette and star; rarely the disk is nearly uniform pale gray, like the upper side of the arms. The larger specimens have the disk 10^{mm} in diameter; length of the arms, about 45^{mm}.

This species is rather common in this region, in deep water; we have also frequently dredged it farther north, in the Gulf of Maine; Bay of Fundy; and off Nova Scotia.

Antedon dentatum Verrill.

Alectro dentata Say, Journ. Acad. Nat. Science Philadelphia, v, p. 153, 1825.
Antedon dentata Verrill, Proc. Boston Soc. Nat. Hist., x, p. 339, 1866.
Alecto Sarsii Düben and Koren, Sv. Vet.-Akad. Handl., 1844, p. 231, pl. 6, fig. 2.
Antedon Sarsii Verrill, Amer. Journ. Sci., vii, p. 500, 1874.

This species was originally described by Say, from a specimen found at Great Egg Harbor, N. J. His description agrees in all respects so well with our smaller specimens, that there can be little doubt of its identity. Moreover, this form occurs in abundance off New Jersey, at moderate depths, but no other species has been taken there, unless in very deep water.

In addition to the numerous specimens from off Martha's Vineyard, we have it from Cashe's Ledge, off the coast of Maine, and from various localities off Nova Scotia, on the fishing grounds. Mr. A. Agassiz, also, took it, off our coast.

Anthozoa.

Of Anthozoa, upwards of thirty species were obtained. Among these are seven species of Pennatulacea and four of stony corals. A list of the species is deferred to the next number. Several very large and conspicuous species of sea-anemones or actiniæ occurred, some of them in great abundance. The following are among the more remarkable species, and appear to be undescribed:

Urticina longicornis V., sp. nov.

A large and very handsome species, remarkable for its parchment-like skin and long, tapering, pink tentacles. It contracts energetically and quickly. Column more or less cylindrical, or hour-glass shaped, usually higher than broad, very contractile, capable of involving the upper portion, which is, for about an inch below the edge (in large examples), softer, lubricous, longitudinally ridged, and brighter colored than the rest; below this the integument is firm, parchment-like, covered with small verrucæ, arranged in vertical lines, often fading out below, to mere wrinkles; the verrucæ are mostly due to the rising of the surface between longitudinal and transverse wrinkles. Disk large, in expansion broader than the column, usually concave. Tentacles not very numerous, large and very long, regularly tapered to slender, acute tips; they seem to be arranged alternately in two or three circles, concentrated toward the margin; the inner row contains only twelve, which stand well apart, and are larger than the rest. Mouth large, with eight large lobes on each side (or four bilobed ones); gonidial grooves large. Color of column, pearly white or rosy white, except the upper, softer portion, which is usually deep orange-red, or chocolate-brown, with paler stripes; disk rosy

white or pale pink, with narrow, deeper pink or purplish radii, which extend around and between the bases of the tentacles, but usually do not reach the mouth; lips reddish or orange-brown, striped with darker; tentacles usually light rose-red, or pink, translucent, often with brighter red on the inner surface and at tip, and frequently with an ill-defined ring of white at the base, and white at tips, outside. The larger specimens are 4 to 6 inches high; diameter of column 2·5 to 3 inches; across tentacles 4 to 6 inches; length of inner tentacles 2 to 2·5 long; ·12 to ·14 in diameter at base.

Taken in small numbers, and only in this region; 120–325 fathoms. It is a very elegant and showy species, and lives well in aquaria.

Urticina perdix Verrill, sp. nov.

Full-grown specimens are very large, often 8 to 12 inches in diameter, in expansion. Form very changeable. Column varying from low and broad to cylindrical and hour-glass shape, often higher than broad; integument soft and smooth, but in partial contraction sometimes covered, near the summit, with small, ovate verrucæ. Disk, in expansion, usually broader than the column, often with the edge broadly undulated or frilled. Tentacles translucent, rather long, and very numerous, forming five or six circles, the inner ones long (1 inch or more), tapered, obtuse, and placed about half way between mouth and margin, the outer ones smaller and crowded. Mouth with large gonidial grooves and strong lateral lobes. Color: column curiously mottled and reticulated with soft, yellowish brown, varying from a pale tint to deep orange-brown; the ground-color is pale buff and the two colors alternate in transverse bands, the darker bands usually wider, below, and often zigzag, or even broken up into squarish patches, while brown lines often cross the pale bands, giving an irregularly checkered pattern. These bands and spots are usually finer and more crowded above; disk usually pale yellowish olive, sometimes purplish, more brownish near the mouth, with faint alternating radii of lighter and darker tints; lips chocolate-brown, or red-brown; tentacles similar to disk, but paler, with two or three broad and ill-defined bands of brownish or purplish, one near the tip, faint, the basal one broader on the sides.

Ordinary specimens are 4 to 6 inches across the tentacles, in expansion, with the column 3 inches in diameter and about the same in height. This is a very handsome species and thrives well in aquaria. Several were kept by us all summer. It does not appear to extend to very great depths; 61–115 fathoms.

Urticina callosa V., sp. nov.

A very large species, with a very thick, firm, leathery integument, covered, especially on the upper half, with irregular, often angular, large low verrucæ or ridges, which fade out into irregular wrinkles below; the verrucæ extend to the uneven edge of the disk, at the base of the tentacles, without any change in the character of the integument, which has a rather smooth, lubricous surface. Large specimens seldom retract the disk and tentacles completely, apparently owing to the firmness and leather-like stiffness of the walls of the body, but smaller ones contract more readily, and have a much smoother surface. The column is usually, in expansion, higher than broad, cylindrical, more frequently smallest at base or, hour-glass shaped, but when handled becomes more or less flattened longitudinally, or collapsed. Tentacles rather short, stout, obtuse, numerous, covering much of the disk, usually extending more than half way to the mouth, changeable in form, but not very contractile, often longitudinally striated or wrinkled. Disk large, usually much broader than the column, and commonly concave. Mouth large, with large, whitish gonidial grooves; side lobes large, unequal, salmon-brown. Base broad, generally deeply concave, commonly enclosing firmly a large mass of mud, etc.; the base is capable of secreting a thin, chitinous pellicle.

Color, generally salmon or orange; column almost always pale salmon or buff, varying to deep salmon; disk most often deep salmon, with paler radii; lips darker salmon or orange-brown; tentacles usually plain deep salmon or orange-brown, with paler striæ. Height often 4 to 7 inches; breadth across expanded disk 6 to 10 inches; length of largest tentacles 1 to 1·25 inch; their diameter ·25 of an inch.

Very common in deep water in this region; 120–335 fathoms. Also northward, in the Gulf of Maine, and off Nova Scotia.

This large species is liable to be confounded with *U. nodosa* (Fabr. sp.), which is almost universally associated with it, has similar habits, and grows nearly as large. The latter can best be distinguished by having the retractile upper part of the column, for a short distance below the margin, smooth, soft, longitudinally ribbed and grooved, and covered with mucus, and highly phosphorescent, like the tentacles, while the rest of the column is firmer, coriaceous, not lubricous, and covered with irregularly scattered, prominent, often very large, rounded tubercles, disappearing below; there is usually a closely adherent, dirty coating over most of the surface; the color of its column is usually dirty whitish, or pale dull red, becoming brighter pink, or even chocolate-brown, on the smooth, upper part of the column; the tentacles are longer and more tapered, and, like the column, are much more retractile.

Urticina consors V., sp. nov.

A delicately colored species, with a soft, smooth integument. Column elongated, in expansion; above, occasionally showing a few warts and longitudinal plications; margin simple. Tentacles numerous, in about four circles, crowded toward the margin; they are rather short and stout, tapered, acute, the outer ones much smaller. Mouth with strong, whitish, gonidial grooves at both ends, and about ten lobes on each side, separated by darker grooves. Color of body nearly uniform salmon, or rosy; tentacles a paler shade of the same, the outer ones with a flake-white blotch at the base, outside; disk pale salmon, with a pale bluish tint, and with flake-white radii, forking at the tentacles; mouth bright orange inside, with lines of reddish brown on the lips. Height, about 2 inches; diameter, 1·5.

All the specimens obtained were on the backs of a brilliantly colored species of hermit-crab (*Parapagurus*, sp. nov.), remarkable for large bright red patches on its legs; 160–458 fathoms. This species may not be a true *Urticina*. It resembles certain species of *Sagartia*, but no acontia were observed.

Actinernus saginatus Verrill, sp. nov.

A large species, with a broad, low column, having a pale, translucent, thick, soft, cartilaginous, or gelatinous test. The column is broader than high, largest above, smooth, or more or less wrinkled. Tentacles not crowded, in two rows, close to the margin, long, tapering, rather slender, acute, decidedly thickened at the base; the outer ones have the thickened, outer, basal swelling continuous with the edge of the disk. Base much smaller than the column, concave, secreting a chitinous pellicle and enclosing a mass of mud, as in *U. callosa*. Color of column, pallid, or bluish white, with a tinge of pink; disk deep orange, with paler radii; lips deep orange-brown; tentacles orange-brown. Diameter of disk, in expansion, about 5 inches; of base, about 2; length of tentacles, 1·5 to 2 inches. The tentacles are contractile. Only one specimen was taken. Station 1029, in 458 fathoms.

Adamsia sociabilis V., sp. nov.

A small, conspicuously colored, abundant species, which is always found on the back of a small hermit-crab (*Hemipagurus socialis* Smith). Color: column translucent, usually conspicuously striped with alternate pink and flake-white longitudinal bands, the latter narrowing upward; tentacles pinkish; mouth with pink lips, crossed by darker lines, between the small lobes. Height, in expansion, about ·5 of an inch (10 to 14^{mm}). Common in 86–300 fathoms.

Art. XXI.—*A New Form of Reversible Stereoscope;* by W. LeConte Stevens.

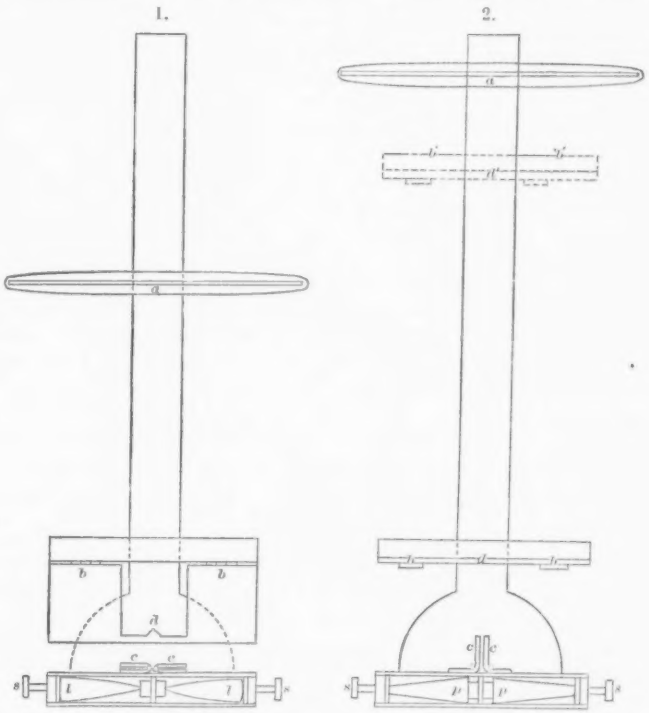
With a view to removing for others the difficulty implied in the binocular experiments on which I based the conclusions expressed in my recent papers, published in the November and December numbers of this Journal, I have devised the following form of stereoscope, which has been found quite satisfactory. Persons possessing no previous muscular training of the eyes have been able with it to secure reversion of relief in the combined picture as easily as they had obtained natural perspective while using it as an ordinary stereoscope. Some of my experiments involved extreme muscular tension; these required the use of the unaided eyes, but a large proportion of the rest can be performed by the aid of this instrument without special discomfort. It has been constructed for me by Messrs. E. & H. T. Anthony & Co., of this city.

The semi-lenses (fig. 1, *l*, *l*), rest in a pair of boxes, with windows in front and behind, to transmit the light. These boxes are separated by a thin partition, on each side of which is a spring against which the thin edge of the semi-lens is pressed by the adjusting screw (*s*) at the base. In front is a pair of brass hinges (*c c*); when pressed flat as in fig. 1, each half of the stereograph is hidden from the eye on the other side; when folded, as in fig. 2, the whole stereograph is made visible to each eye. Attached to a sliding cross-bar is a wooden screen (*b*, *b*), moving on hinges; when this is pressed down flat, as in fig. 1, the view of the stereograph is unobstructed; when lifted up, as in fig. 2, the window at the middle permits the left half of the stereograph to be seen by the right eye, while the right half is obscured; and vice versa for the left eye. From the top of this window is a small projection (*d*). The stereograph rests upon its movable cross-bar (*a*) which slides upon a longitudinal strip about 30^{cm} in length.

The semi-lenses are easily removable at will, and a pair of prisms (*p p*) the refracting angle of which is 12°, can be substituted, but with their bases pressing against the springs instead of the screws.

To secure natural perspective through the semi-lenses, press the brass and wooden screens flat (fig. 1) and use the instrument as an ordinary stereoscope. Assuming the stereographic interval to be average, and the distance between the observer's eyes to be not greater than usual, comfortable vision will be secured by turning the adjusting screws until the semi-lenses are pressed as near as possible together. The light which enters the pupils then passes through the thicker part of each

semi-lens, and the optic angle is positive and small, or the visual lines may be sensibly parallel. If the observer's interocular distance is much greater than usual, the rays of light which he receives will be transmitted still nearer the base of the semi-lens, and slight optic divergence is necessary. This is avoided by giving a few leftward turns to the screw, permitting the semi-lenses to be pressed a little farther apart by the opposing springs. The same can be done to secure comfortable vision when the stereographic interval is great; pictures 10^{cm} apart can thus be viewed without discomfort, and without any very objectionable degree of coloration in consequence of want of



achromatism in the semi-lenses. By now turning the screws so as to press the glasses closer together, any degree of optic divergence may be attained that the observer is willing to endure, while the picture is still seen in natural perspective, distances being apparently slightly magnified, and diameters also in the same ratio.

To secure reversed perspective, lift up the wooden screen, fold the brass hinges outward in front, and substitute the

prisms for the semi-lenses, as in fig 2. Slide the stereograph nearly to the end of the stereoscope. Physiological perspective is at once reversed; whether this is enough to overpower the other elements of perspective must depend upon the nature of the picture. If the stereograph be that of the moon, the reversion is complete; if of terrestrial scenery, some objects may be apparently transposed in position while others are not. The same picture may be examined successively with each illusive effect several times in as many minutes. As soon as reversion is attained, the stereograph may be drawn up as close as may be convenient.

If both semi-lenses and prisms are discarded, the instrument becomes a direct-vision stereoscope; in some respects similar to that described by Professor William B. Rogers in 1855. To secure natural perspective, press the screens flat, pull the stereograph up as close as possible, and gaze as if through it at a remote object, with the muscles of the eyes relaxed. The two pictures, imperfectly focalized, are dimly seen apparently to overlap. The stereograph is then pushed out to the end of the stereoscope, and the pictures are binocularly combined by optic divergence. The stereograph may now be pulled up as near as convenient.

To secure reversion of perspective by direct vision, fold the brass hinges and lift the wooden screen, as in fig. 2. Push this out ($b'\,b'$) as near as possible to the stereograph at the end of the instrument, then pull it up, keeping the gaze fixed upon the projection (d') at the top. This grows dim as it approaches its previous position. Without changing the direction of the visual lines, except slightly to lower them, transfer the attention to the stereograph beyond. The combined picture is seen in reverse perspective, apparently much smaller and nearer than when the prisms were employed.

Those who have tried this instrument thus far have usually succeeded at the first attempt, for either natural or reverse perspective, when the glasses were used. Several trials are often necessary before success is attained by direct vision, but the variation in perspective thus attained is much more striking. But little experiment is needed to prove to any one who is thus successful that in the localization of objects in the binocular field of view presented by the stereograph, the current theory of successive triangulation by intersection of visual lines is inapplicable. The only substitute that covers the facts which the geometric theory fails to account for, is that of associated muscular action, which applies to divergence as well as convergence of visual lines.

The use of adjusting screws for the semi-lenses of the stereoscope is, of course, not a novelty. They were thus applied by

Duboscq, about 1850, to one of Brewster's stereoscopes and also subsequently by Helmholtz. A similar application is especially described by Professor Emerson in this Journal, Nov., 1861, and Emerson's stereoscope was for a number of years made by Messrs. Anthony & Co. of New York. It would indeed be difficult to evolve any wholly new principle in the construction of stereoscopes. The present instrument was devised for a specific purpose, which it accomplishes successfully.

40 West 40th St., New York, Jan. 21st, 1882.

ART. XXII. — *On the Magnetic Properties of a Specimen of Nickeliferous Iron from St. Catarina, Brazil, as first pointed out by Lawrence Smith, by* HENRI BECQUEREL;* *with a note by* J. LAWRENCE SMITH.

MR. LAWRENCE SMITH has recently discovered in a native iron, found in 1875 in the province of St. Catarina of Brazil, a singular physical property, viz: that in its natural condition it is very feebly attracted by the magnet, but if a fragment is heated to redness and subsequently cooled, there is manifested a magnetic property with the usual intensity of iron.†

The specimen which I have had occasion to study was furnished me from the collection at the Garden of Plants. A small bar was prepared, weighing 2·731 grams, and 18·5^{mm} long, 5·2^{mm} broad, and 3·8^{mm} thick. This bar was compared with a small bar of Swedish iron, of the same length and width, with about the same dimensions. The experiments made were by means of the electro-magnetic balance described in a preceding memoir.‡ The following results were obtained:

St. Catarina Iron.

Intensity.	Swedish iron.	Natural condition or heated to 230°.		Heated to redness.			Heated and tempered.	
Sine of the deviation of the needle.	Magnetic weight.	Magnetic weight.	Relation to Swedish iron.	Magnetic weight.	Relation to Swedish iron.	Relation to the native iron not heated.	Magnetic weight.	Relation to Swedish iron.
	mmg.	mmg.						
0·1500	60	3·2	0·053	64	1·066	20·	60	1·000
0·3000	238	12·6	0·053	244	1·025	19·3	232	0·974
0·5600	759	40·5	0·054	702	1·004	18·8	749	0·986
0·7000	1110	58·8	0·053	----	----	---	----	----
0·8300	1489	77·7	0·052	1489	1·000	19·1	1454	0·976

* Translated from Comptes Rendus, xciii, p. 794, 1881.

† Comptes Rendus, xcii, p. 848.

‡ Annales de Chimie et de Physique, 5th series, xvi. 1879. (Magnetism of Nickel and Cobalt.)

It is apparent, in the first place, that in the natural state, the small bar of St. Catarina iron is very much less magnetic than the Swedish iron. When the former was heated to 230°, it assumed a rose color, but the magnetic attractions on the balance were the same as before heating; when re-heated for an hour to a bright red heat, on lime, to avoid too much oxidation, and then slowly cooled, the iron was twenty times more magnetic than in its natural condition, and as magnetic as the Swedish iron. Its weight had been increased 35^{mg}. Finally, when heated a second time and plunged in cold water, its specific magnetism varied but very little, and remained the same after repeated heating and tempering.

To study this iron under conditions more or less removed from its magnetic saturation, two other little bars were experimented with.

Bar No. 2.—Weight, 1·245 gr.; length, 30 mm. breadth, 4 mm.; thickness, 3 mm.

Intensity.	Natural state.	Heated to redness.	Relation.
0·1525	1·7 (?)	36·	21· (?)
0·3000	5·	130·	26·
0·5600	16·	407·	25·4
0·8100	30·	749·	24·9

Bar No. 3.—Weight 0·253 gr.; length, 13 mm.; breadth, 2·25 mm.; thickness, 1·2 mm.

Intensity.	Natural state.	Heated to redness.	Relation.
-----	--	---	---
0·3020	1·8 (?)	41·	23· (?)
0·5600	5·	123·	24·6
0·8141	9·5	229·	24·1

The native iron of St. Catarina has been carefully studied by M. Damour and MM. Daubrée and Meunier, who have attributed to it a meteoric origin, and who have found that it contained about 34 per cent of nickel. The remarkable effect manifested when it is heated appears to be due principally to the presence of nickel and a crystallization effected at a very low temperature.

I therefore undertook a series of experiments, to see whether pure iron and pure nickel crystallized in the cold did not exhibit the same property. To try this, small cylinders of iron and nickel were prepared by depositing these metals upon a platinum wire by electrolysis. The deposit took place slowly at the ordinary temperature, and the deposited metals were crystallized. The bars were studied by the aid of the balance, then heated to redness and re-examined. The iron in the conditions under which I operated presented after heating no notable change in its magnetic properties. This was not true of the nickel crystallized in the cold, for it presented after the heating a considerable augmentation of its magnetic property. The following are some of the results obtained with this metal:

Nickel deposited by the pile.

First bar.—Weight 2·442 gr.; length 40 mm.				Second bar.—Weight 4·484 gr.; length 50 mm.			
Intensity.	Not heated.	Heated.	Relation.	Intensity.	Not heated.	Heated.	Relation.
0·1500	34 mgr	216 mgr	6·37	0·1708	80·5 mgr	434 mgr	5·39
0·3000	147	589	4·00	0·2885	320·5	1010	3·15
0·4200	310	909	2·93	0·5480	1132·5	2313	2·04
0·5900	589	1363	2·33	0·7758	1982·5	3470	1·75
0·8500	1103	2043	1·85	-----	----	----	---

The bars that were examined contained in their axes a platinum wire, thus forming a kind of tube; and as their section is small compared with their length, they are much nearer their point of magnetic saturation than the bars of native iron already examined. In regarding the rapid increase of the relation as recorded in the last column of the above tables, when we recede from the point of saturation, we recognize that the increase of the magnetic properties of the nickel crystallized in the cold is of the same order of phenomena as that observed in the St. Catarina iron.

It might be imagined, that on forming with the native metal bars such as No. 2 and No. 3, of which the sections are smaller and smaller in relation to their length, that we approximate to the magnetic saturation and would obtain numbers nearer to those which were found for the nickel in the condition of the preceding experiments; but on the contrary, in the case of these two bars, the magnetic relations before and after the heating is greater for the second than for the first. If the facts be considered which I have established in the memoir previously referred to, it will be recognized that the characteristics presented by the St. Catarina iron indicate that the magnetic conditions to which it has been submitted are far removed from those of saturation.

The magnetic capacity of nickel is greater in proportion to the distance the molecules of this metal are removed from each other; it therefore tends to become equal and even a little superior to that of iron. Perhaps the dissemination of the nickel in the mass of native iron under consideration is more favorable to the manifestation of the energetic magnetic property of this metal; in fact observation proves that after the heating of the nickel which accompanies the iron, the nickel behaves like the iron. The crystalline condition of the native iron not reheated appears as in the pure nickel to be the cause which opposes the magnetic manifestations.

We necessarily conclude from this research that the native iron from St. Catarina has been crystallized at a low temperature. This conclusion does not permit of forming a correct hypothesis of the meteoric or terrestrial origin of the iron.

NOTE BY J. LAWRENCE SMITH.

After completing my researches on the Ovifak iron and dolerite of Greenland,* which had occupied me off and on for several years, establishing indisputably the terrestrial origin of that iron, I was induced to examine into the nature of some other native irons, whose origin was somewhat equivocal. One that has been supposed to be of meteoric origin is that discovered, in 1875, at St. Catarina in Brazil. Having obtained specimens of this iron, I tried to apply to it the same rules of investigation as I had done to the Greenland iron, but my series of specimens would not permit of this and the question was left in doubt. My first object was to separate a pyritic mineral associated with the iron; but owing to the fact that the metallic iron permeated the pyrites in numberless filaments, it was impossible to conduct this separation by means of the magnet, nor have I as yet been able to devise any other method. While applying the magnet to various parts of the pure metal, it was found that many of these small pieces did not respond to the attraction of the magnet, but when these pieces were flattened out by being hammered between two bright surfaces, that the flattened metal would be attracted by the magnet, and if heated to redness would become as susceptible to the magnet as pure iron. The iron of the native mineral, as I had previously ascertained, contained as much as 34 per cent of nickel, but the mere presence of the metal in no manner sufficed for an explanation of this phenomenon: for the Oktibbeha meteoric iron contains over 45 per cent of nickel, and is under all circumstances affected by the magnet as readily as any other meteoric iron. I made a number of experiments, and satisfied myself that many pieces of the St. Catarina iron in its natural condition were *one or two hundred times* less magnetic than pure iron; in other pieces the difference was much less, but after heating they all became equally magnetic. Having no magnetic balance I sent a detailed account of my experiments to the French Academy of Science, with a request that M. Becquerel should examine it with his magnetic balance: this he has done and his interesting results are given in the pages preceding.

While he does not mention having tried the effect of mechanical compression on the crystalline nickel as deposited by electricity, it may be that this compression would have some effect in increasing its normal magnetism. I hope soon to investigate further this iron to settle the question as to its possible origin.

* Comptes Rendus, vol. xci. and Annales de Chimie et de Physique, 5e ser., xvi, 1879.

ART. XXIII.—*Origin of Jointed Structure in undisturbed Clay and Marl deposits;* by JOHN LECONTE. (From a letter addressed to Professor J. D. Dana, dated Berkeley, California, Jan. 10, 1882.)

My Dear Sir:—In reading Mr. G. K. Gilbert's very interesting and suggestive article on "Post-Glacial Joints," (this Journal, III, xxiii, 25–27, Jan., 1882), it occurred to me that the key to the true explanation of the jointed structure of the clays and marls, constituting the floors of the deserts of the Great Salt Lake basin, might be found in the analogous phenomenon, observed at the present time, in the desiccation of the fine sedimentary deposits forming the deltas along the Sacramento River and other valleys in California. The reclamation of the Tulé or swamp-lands of these deltas, by excluding the overflows of the rainy season by means of extensive levees, has brought under notice the very striking and conspicuous phenomena of immense vertical cracks or joints, evidently due to the shrinkage of these marshy deposits during the progress of their desiccation. These cracks, by their intersection, form more or less rude approximations to quadrangular or hexagonal prismatic blocks. In some places they are from 10 to 15 feet across at the surface, and extend down probably to the bottom of the deposit, which reposes upon a stratum of hardpan, frequently 60 feet or more below. These cracks sometimes extend across the levees, thus originating serious crevasses and disastrous floodings.

The coefficient of contraction or shrinkage from loss of moisture in such deposits is simply enormous. Thus the finer sediments, due to the recent operations in hydraulic mining, in certain situations, form deposits from four to six feet deep over the older beds of sand along the banks of the Feather River (a tributary of the Sacramento). When this stratum of clay is subjected to the desiccating influence of the prolonged dry season, cracks are formed by shrinkage extending to the bed of sand, and so large that a man can walk on the sandy substratum between the vertical prismatic columns.

It seems to me that in these phenomena we have reproduced in *minimis* under our very eyes, the counterpart of what took place on a gigantic scale in the Salt Lake basin through the powerful desiccating influence of the arid climate which succeeded the Glacial epoch.

It is evident that when such cracks or joints become filled, by subaerial agencies, with sand and other materials, the subsequent lines of erosion must necessarily follow these channels

of rupture in the more compact subaqueous deposits of clay and marl.

I am indebted to my son, L. J. LeConte, for the facts above recorded. He had the opportunity of carefully observing the phenomena under consideration, in connection with the reconnaissance of the Sacramento valley, in relation to the improvement of the navigation of the river as well as our great engineering problem of the disposal of the debris resulting from hydraulic mining.

Of course every one is familiar with the cracks in mud or clay due to the shrinkage consequent upon drying; but, as far as I am aware, no one has called attention to the fact that they may be developed on so large a scale as to become an important factor in the physical geology of past ages.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Relation between the Optical and Thermal phenomena of Liquid Organic substances.*—Brühl has continued his researches on the connection between the physical properties of organic bodies and their chemical constitution, and in his last paper discusses the relation between the optical and the thermal phenomena observed in organic liquids. He finds: 1st, that progressive oxidation has the same influence on the optical as on the thermal properties; the refractive power, represented by $\frac{A-1}{d}$, diminishing as the amount of oxygen is increased, precisely as the heat of combination diminishes. Removal of hydrogen, or its replacement by oxygen produces the same effect; so that both the above physical values are greater for the hydrocarbons than for the alcohols, aldehydes, acids, etc., derived from them. The differences, however, diminish as the molecular weight increases, that between propyl-alcohol and propyl-aldehyde being smaller than between ethyl-alcohol and acetic aldehyde. 2d, halogenization has the same influence, both the refractive power and the heat of combination becoming smaller as the chlorine atoms increase. The constant for bromine is less than for chlorine, and for iodine it is still less. 3d, in the homologous series of alcohols, acids and ethers, both the optical and the thermal constants increase with increasing amounts of carbon and hydrogen, though the successive differences diminish as the molecular weight rises. 4th, the refractive power of isomeric bodies of equal saturating power is the same for all and is therefore independent of the atomic grouping, as the author had proved some time ago. The researches of Louguinine, Berthelot and others have shown the heat of combustion to be also the same for such bodies. 5th, in polymers, these phys-

ical constants are both smaller than those of the bodies producing them, and they diminish as the molecular weight increases; *i. e.*, the greater the number of the condensed molecules. 6th, isomeric bodies of unequal saturating power have different refractive powers; bodies in which doubly united atoms exist have a larger value of this constant than their isomers not having this union; and the value is larger when carbon atoms are doubly united than when carbon is thus joined to oxygen. Longuinine has proved the same to be true of the heat of combustion. Thus an unsaturated alcohol, as allyl alcohol, has a higher refractive power and combustion value, than the isomeric bodies propyl-aldehyde, or acetone. 7th, since if two bodies having the same molecular formula give different quantities of heat on combustion, they must contain different quantities of energy, it follows that the internal energy of bodies containing doubly combined atoms is greater than that of their isomers which have only singly united atoms. The energy of a body consists of the *vis viva* of its moving particles and of its interior work, the latter only, tending to diminish the forces uniting these particles and so to produce disaggregation. But the *vis viva* of isomeric bodies is equal; hence the difference of energy observed in these bodies represents a difference of internal work, the greater energy representing a looser aggregation of the atoms. Because greater energy is evolved in the case of doubly combined atoms, therefore it follows that the so-called double union of atoms shows not a more intimate, but on the contrary a weaker attraction, than single union; and hence the assumption of a stronger or denser union in unsaturated bodies, when their atoms are doubly combined, is directly the reverse of the fact. This conclusion is supported by Kopp's and by Buff's results showing that the volume of a body containing doubly combined atoms is greater than that of one containing only singly united ones; and also by the rule established by Kekulé that on oxidation of a body with doubly united atoms the molecule first breaks at the double union.—*Ber. Berl. Chem. Ges.*, xiv, 2533, Nov. 1881. G. F. B.

2. *Simple Dissociation Apparatus.*—Tommasi has described a simple apparatus which he called a *dissocioscope*, for showing the dissociation of ammoniacal salts. It consists of a tube of glass 20 to 25 centimeters long and 3 or 4 centimeters in diameter. By means of a platinum wire a slip of blue litmus paper, previously moistened with a solution of ammonium chloride, is suspended in the tube. The solution should be exactly neutral and be completely saturated. The paper is dipped in the solution, pressed for an instant between sheets of blotting paper and while still damp introduced into the tube. If now this tube be plunged into a cylinder containing boiling water, the ammonium salt is dissociated and the blue litmus paper becomes red. On placing it in cold water the dissociated ammonia and hydrogen chloride re-unite and the paper becomes blue again. This may be repeated any number of times at pleasure. Of course by using the bromide,

sulphate, or nitrate of ammonium the dissociation of these salts may be shown.—*Bull. Soc. Ch.*, II, xxxvi, 545, December, 1881.

G. F. B.

3. *On the Effect of Oxides on the Decomposition of Potassium Chlorate.*—Mills and Donald, continuing the researches upon the action of oxides upon salts begun by the first-named chemist, have studied the action of these oxides upon chlorates, a reaction observed by Dobereiner fifty years ago. The oxide employed was ferric oxide, purified by several precipitations, and ignited. The chlorate was several times recrystallized. The apparatus consisted of a shallow iron pot, within which was a low stage of porous tile, upon which was placed the bulb of a Schloesing's gas regulator, with the porcelain crucible in close proximity to it, covered by its lid. A thermometer bulb was placed near it, the iron pot was covered and heated with a Fletcher's burner. The air bath was first heated for a half-hour to the temperature of the experiment. The crucible with its mixture was inserted, and the heat continued for four hours. At the end of the time the crucible was removed, cooled in a desiccator and weighed. Five grams of chlorate were taken in each experiment, the quantity of oxide being gradually increased from a decigram to ten grams, the temperature being kept at about 195°. If the action of ferric oxide upon potassium chlorate be similar to that of an ordinary oxide upon an ordinary salt the numerical results should admit of representation under some form of the general equation $E = \frac{\alpha x y}{x_r + y_r}$ in which E is the chemical effect on oxygen expelled, x and y are respectively the masses of oxide and chlorate, x_r and y_r are the residues of these masses after action, and α is a factor of chemical effect, the number of chemical units of oxygen expelled per unit of oxide. The results suggest that the values of α are inversely proportional to the values of x. Calculation upon this hypothesis gave results closely agreeing with experiment. When x is very small, $\alpha = 3{\cdot}3028$, and $(Fe_2O_3)_2$ expels O_{10} or a unit of the oxide acts on rather more than a unit the chlorate. When x is very large, $\alpha = 0{\cdot}27240$, and the five grams of chlorate reaches the limit of 0·1775 gram oxygen expelled. Moreover as the mass of oxide increases its efficiency decreases. Inasmuch as in the action of ferric oxide on potassium carbonate, the factor of chemical effect, in the first stage, is inversely as the mass of oxide, the authors regard the entire course of the action of ferric oxide upon potassium chlorate as strictly analogous to the first stage of the action of the same oxide on potassium carbonate. This case of chemical change then presents nothing peculiar or abnormal and the name catalysis ceases to be applicable to the reaction now considered.—*J. Chem. Soc.*, xli, 18, Jan. 1882. G. F. B.

4. *On the Freezing point of Sulphuric acid of different Degrees of Concentration.*—Lunge has determined the point at which sulphuric acid of various strengths solidifies when exposed to cold. A freezing mixture of three parts ice and one of salt was used, in

which the thermometer sank to −20°. The first separation of crystals required prolonged cooling; but once effected, it takes place much easier and always at the same temperature. That temperature at which the first crystals appeared was called the freezing point. The fusing point could not be fixed with the same exactness. The thermometer was corrected, the specific gravity determined on an accurate balance and reduced to 15° by Schaeppi's tables. The Baumé degrees were calculated according to the rational aræometer, $d = \frac{144{\cdot}3}{144{\cdot}3 - n}$. The results obtained are given in the following tabular form:—

Sp. gr. at 15°.	Baumé.	Freezing point.	Fusing point.
1·671	58°	Liquid at −20°	----
1·691	59°	----	----
1·712	60·05°	----	----
1·727	60·75°	−7·5°	−7·5°
1·732	61·0°	−8·5°	−8·5°
1·749	61·8°	−0·2°	+4·5°
1·767	62·65°	+1·6°	+6·5°
1·790	63·75°	+4·5°	+8·0°
1·807	64·45°	−9·0°	−6·0°
1·822	65·15°	Liquid at −20°	----
1·842	66°	----	----

Ber. Berl. Chem. Ges., xiv, 2649, Dec. 1881. G. F. B.

5. *On the action of Water on Bismuthous iodide as illustrating Chemical change.*—Pattison Muir has suggested the action of water on bismuthous iodide as a lecture experiment well adapted for illustrating the influence of (*a*) time, (*b*) temperature and (*c*) mass, on a chemical change. Two forms of the experiment are given. In the first, a quantity of hydriodic acid—one part of strong acid to 100 of water—is divided into two equal parts. One is heated to boiling, the other remains cold; a small quantity of the cold solution is diluted with about three times its own bulk of water, a little of this is again diluted with about three or four times its volume of water. The four liquids are placed in beakers on white paper, and a few grains of solid bismuthous oxide is shaken into each. In the cold and strongest liquid brown BiI_3 is produced; in the hot liquid red BiOI; in the cold moderately dilute liquid, BiOI; and in the most dilute, there is little or no action. The second form of the experiment is performed by pouring a little of a solution of BiI_3 in strong hydrogen iodide into each of three beakers, the first of which contains 100 c.c. cold water, the second, the same at 90° to 100°, the third 500 c.c. cold water. Brown BiI_3 falls in the first, red crystalline BiOI in the second, and red BiOI but in smaller quantity, in the third. The brown BiI_3 passes into the red BiOI on standing; addition of strong HI reproduces brown BiI_3.—*J. Chem. Soc.*, xli, 4, Jan. 1882. G. F. B.

6. *On the Splitting of Petroleum hydrocarbons at low Temperatures.*—Gustavson has observed that when in hydrocarbons obtained either from American or Caucasian petroleum, alumi-

num bromide is dissolved and hydrogen bromide gas is passed into the liquid, the whole heated in a paraffin bath, the mass separates into two layers, the composition of the lower one being always the same. It is a pretty thick liquid, of the consistence of aqueous glycerin, orange-red in color, not solidifying at $-15°$, permanent at $100°-120°$, but decomposing at higher temperatures into gaseous products, insoluble in the hydrocarbons from which it is formed, and in carbon disulphide, but miscible in all proportions with ethyl bromide. It has probably the formula $AlBr_2C_4H_5$. Besides this substance gaseous products are evolved, not condensible in a freezing mixture, and consisting of lower members of the series.—*Ber. Berl. Chem. Ges.*, xiv, 2619, Dec. 1881. G. F. B.

7. *On the Occurrence of Metaisocymene in Rosin oil.*—Of the six theoretically possible cymenes (propyl-toluenes) paranormalpropyltoluene has been obtained by Paterno and Spica, orthonormalpropyltoluene and metanormalpropyltoluene by Claus, and paraisopropyltoluene by Jacobsen. KELBE has now detected the existence of metaisopropyltoluene in the product of the dry distillation of rosin. From the lighter portions of the distillate, fractions were separated boiling from 108° to 115°, 160° to 170°, 170° to 180°, and 180° to 190°. In the first toluene was present and in the others cymene. To prepare the latter, the fractions from 160° to 190° were again fractionated, and the product treated for some hours with concentrated sulphuric acid on the water bath. Dilution with water and neutralization with barium carbonate gave the cymene-sulphate. But on saturating the acid with hydrogen chloride and heating in sealed tubes to 180°, cymene itself was obtained. From 15 kilograms of rosin-spirit, 800 grams of cymene were procured. On oxidation with chromic acid, isophthalic acid was obtained; thus proving the cymene to belong to the meta-series $C_6H_4\begin{cases}CH_3\,(1)\\C_3H_7\,(3)\end{cases}$. To determine the structure of the propyl group, isopropyl iodide was made to act on toluene in presence of aluminum chloride. A cymene was obtained identical with that obtained from the rosin-spirit. Thus proving the former to be metaisopropyltoluene $C_6H_4\begin{cases}CH_3\\CH\\CH_3\end{cases}\begin{cases}CH_3\,(1)\\(3)\end{cases}$. Several compounds of the new cymene are described.—*Liebig's Ann.*, ccx, 1, Oct., 1881. G. F. B.

8. *On the Aldehyde-nature of living Protoplasm.*—Starting from the fact observed by them, that living cells behave differently from dead ones, that living protoplasm has the power of reducing very dilute solutions of silver which dead protoplasm has not, LOEW and BOKORNY have concluded that living protoplasm is chemically of the nature of an aldehyde. Reinke suggested in it the presence of formic aldehyde, the authors have examined the distillate from algæ with a negative result. Their own view seems to them the more probable.—*Ber. Berl. Chem. Ges.*, xiv, 2441, Nov. 1881. G. F. B.

9. *On the Viscosity of Gases at High Exhaustions.*—In a paper read before the British Association in 1859, Maxwell presented the remarkable theoretical result that the coefficient of friction or the viscosity between layers of gas having different velocities of translation should be independent of the density of the gas. Previous experiments do not seem to confirm this view and Professor Crookes has lately investigated the subject, bringing to the study great experimental skill gained by long experience in obtaining and measuring high exhaustions. For the many refinements of the apparatus we must refer the reader to the original memoir. In its main feature the apparatus consisted of a torsion pendulum, composed of a plate of mica one-half of which was blackened, which was suspended by a long silk fiber in a tube filled with the gas whose viscosity at different exhaustions was to be examined. The movements of this torsion pendulum were observed by means of a beam of light which was reflected from a mirror placed upon the pendulum. Since the viscosity of the gases dampened the vibrations of this torsion apparatus (which was set in vibration by the radiometer effect on the semi-blackened plate of mica), a careful analysis of the decrements of the swings were necessary. Several curves illustrating the viscosity by means of this decrement in the swing are given; and a careful analysis on hydrodynamical principles by Professor G. G. Stokes is appended to Professor Crookes' paper. The following is a table of the results obtained by different observers.

	Graham.	Kundt and Warburg.	Maxwell.	Crookes.
Air	1·0000	1·0000	1·0000	1·0000
Oxygen	1·1099	"	"	1·1185
Nitrogen	0·971	"	"	0·9715
Carbonic anhydride	0·807	0·806	0·859	0·9208
Carbonic oxide	0·971	"	"	0·9715
Hydrogen	0·4855	0·488	0·5156	0·4439

Professor Crookes believes that his results are more accurate than those of previous observers. He has obtained a much lower viscosity in the case of hydrogen and believes that its accurate obedience to Maxwell's law is a proof of its purity, for any impurity arising from admixture of other gases impairs the results. The results uphold Maxwell's theory in general, and the more perfect the gas the nearer the agreement. Professor Stokes states in his discussion of Professor Crookes' results that the direct solution of the problem of the movement of a lamina like a mica plate in even a perfect fluid cannot be solved; but theory enables one to compare the viscosities in different media under certain conditions of similarity. Professor Stokes is accordingly led to the following law.

"If any pressure be taken in one gas and the pressures found in other gases for which the coefficients of viscosity are as the densities (pressures which have been defined as 'corresponding'), then if another system of pressures be taken proportional to the former the pressures in the new system will also correspond; and

consequently the ratio of the coefficients of viscosity of the different gases will be the same for the pressures in one such system as in another." He remarks "that this law is in accordance with Maxwell's law but does not by itself prove it." The constancy or tendency toward constancy is the viscosity as the rarefaction goes on, which is shown by Professor Crookes' experiments, is sufficient, in Professor Stokes' opinion, to establish Maxwell's law.—*Phil. Trans. of the Royal Society*, Part II, 1881, pp. 387–446.

J. T.

10. *Contributions to the Theory of Electro-magnetism.*—Two magnetic influences in different planes upon the particles of steel seemed to W. Siemens to require careful study and he has therefore experimented upon the magnetism of iron rings of different dimensions. These rings were simply hollow cylinders which were wound from end to end parallel to the axes of the cylinders, and magnetised by currents passing through these windings. At the same time the cylinders were surrounded by transverse windings. It was found that the magnetism produced in the ring was diminished by the simultaneous action of the windings which were perpendicular to the axis of the cylinder. This fact leads the author to theorize upon the arrangement of the polar particles and to modify previous theories. He calls attention to the advantages which the apparatus we have described possesses both to the investigator and to the practical electrician. In conclusion he experiments upon the shielding influence of iron covers or mantles to electro-magnets and arrives at some conclusions which appear to differ from the generally received opinions upon this influence. He promises further experiments upon this point.—*Ann. der Physik und Chemie*, No. 12, 1881, pp. 635–656.

J. T.

11. *Disintegration of Electrodes by Positive Electricity.*—Reitlinger and Wächter have carefully studied the formation of Lichtenberg's figures and conclude that the positive figures are due to conveyance of small material particles from the positive electrode and that the negative figures are due to the mechanical effect of the discharge of gases.—*Ann. der Physik und Chemie*, No. 12, 1881, pp. 591–610. J. T.

12. *Upper Limit for the Kinetic Energy of Moved Electricity.*—Maxwell in his Electricity and Magnetism, vol. ii, describes an apparatus by which he hoped to detect the inertia of electricity if any such property existed. The results obtained by the apparatus however were negative. Hertz, without reference to the unsuccessful attempts of Maxwell, essays to detect this inertia by a different method. A current of electricity was conducted through a thin metallic plate, approximately of an elliptical shape. The battery current ran to the extremities of the major axis, and the terminals of a galvanometer were connected with the ends of the minor axis. The metallic plate was formed of silver deposited upon glass, and the needle of the galvanometer was brought to rest by scraping away a portion of the silver coating, at the side

of the plate and also by forming derived circuits between the ends of the major and minor axes. In fact the whole arrangement resembles that of a Wheatstone's bridge in which all the branches were confluent. This plate was then made to revolve about an axis perpendicular to the middle of the elliptical plate, and various ingenious arrangements were made to allow the terminals of the galvanometers and those of the battery to follow the motions of the plate. If the electrical current possessed inertia, a difference of potentials would be created by the revolution of the plate. This difference of potential being formed at the extremities of the minor axis of the ellipse would cause a current in the galvanometer whose terminals were connected with the ends of this axis. The various errors incident to this method of experimenting were closely examined and the results of the experiment appeared to the writer to warrant the assertion that he could wager 3480 to 1 that no movement of the needle of the galvanometer greater than one of his scale divisions could be ascribed to the inertness of the electricity. His calculation leads him to the formula $\mu = \frac{\varphi d}{4 J \omega}$ in which μ is the kinetic energy of a current of the magnetic density of 1 in a cubic millimeter of a silver conductor, φ the difference of potential between the ends of the minor axis, d the thickness of the metallic coating of the revolving plate, J the strength of the current passed through the plate, and ω the angular velocity of the plate. The value obtained for μ was $\mu = 0{\cdot}0000185$ mm.^{2} for one scale division which the author selected. He is led to believe that the value of μ would be much larger in liquids and that a positive result could be obtained with them if the difficulties of experimentation could be overcome.—*Ann. der Physik und Chemie*, No. 12, 1881, pp. 581–591. J. T.

13. *Electrical Units recommended by the Electrical Congress of* 1881.—(1.) The fundamental units are the centimeter, the gram and the second (C. G. S.). (2.) The volt and the ohm retain the present value, viz: 10^8 and 10^9. (3.) The resistance of one ohm will be represented by a column of quicksilver, of 1 millimeter square, in section, at 0° C. (4.) An international commission shall decide by new experiments what length this mercury column of 1 millimeter square section should have in order to represent the ohm. (5.) The current through one ohm with the tension of one volt is called an ampère. (6.) The quantity of electricity afforded by one ampère in one second is called a coulomb. (7.) A farad is defined to be that capacity by which one coulomb in one farad gives a volt.—*Ann. der Physik und Chemie*, No. 12, 1881, p. 708. J. T.

14. *Elementary Lessons in Electricity and Magnetism;* by Silvanus P. Thompson. 446 pp. 12mo. London, 1881 (Macmillan & Co.)—The beginner who wishes to make himself acquainted with the fundamental experiments of Electricity and Magnetism, and with the principles which have been deduced from them, will

find this little book an excellent guide. It is written from the modern standpoint, avoiding the use of old phraseology so likely to mislead the beginner, and explaining the not always simple ideas now accepted, in clear and intelligible form; the student who has mastered it will be in a position to go forward with more advanced treatises without having anything to unlearn. There is much fresh matter introduced into the text, but in this respect the figures are not quite all that the book deserves.

II. Geology.

1. *Glacial Erosion in Maine;* by Professor George H. Stone, of Colorado College. Proc. Portland Soc. Nat. Hist., Nov. 21, 1881.—Professor Stone treats in this paper of the composition and distribution and depth of the till in the State of Maine; of the effect of the ground moraine, where thick, in preventing abrasion; of the origin of the lake basins of Maine, whether by erosion or not; of the scarcity of organic matter in or beneath the till; of the probable rarity of sub-glacial streams; and, thence, of the small amount of glacial erosion in Maine. The average depth of the till is stated to be probably between 30 and 50 feet. The rarity of sub-glacial streams is sustained for the following reasons: the fact that no stratified deposits and only a moderate amount of glaciation have as yet been found in or beneath the ground moraine; that the direction of the valleys is not that of the glacial movement, and is sometimes transverse to it; that there were no peaks or ridges rising above the glacier to occasion the formation of crevasses; that the capping of ice over the hills was so thick that the ice may have moved independently of the hills and valleys beneath; and that the pressure of ice was so great that the lower part of the ice could hardly have been subjected to the strains necessary for making crevasses.

Another reason mentioned is that no pot-holes have been found except within a few miles of the sea. But no pot-holes could have been formed from the fall of water in crevasses while the ice was in motion. In borings by waters to make a cylindrical pot-hole, the tool has to work as truly about a center as in the use of a carpenter's augur. A motion of even a yard a century would elongate it.

2. *Glacial phenomena on the Delaware.* — Professor G. F. Wright, in a paper on the age of the Paleolith-bearing gravels in Trenton, New Jersey, states that these gravels rise to about 40 feet above present high-water level, (Trenton being at the head of tide-water); and that the Philadelphia brick-clay, which contains occasional bowlders, has a height of 150 feet above the river—a height "maintained with tolerable constancy up the Delaware as far as Easton, where the bed of the river is 157 feet above tide-level." This clay "rests unconformably upon the older gravel formations." In the Lehigh valley, at Bethlehem, a few miles above its junction with the Delaware valley,

this clay contains scratched pebbles, and overlies coarse gravel at a height of 180 feet above the river.

Professor Wright remarks that the area of the part of the Delaware valley that was covered by the ice was not far from 6,000 square miles, and that the thickness of the ice was probably about 1,500 feet; and, further, that, with the water at Trenton 150 feet deep, as the clay-beds would seem to indicate, the flooded river, flowing at a rate at least five miles an hour, would have carried off all the ice of the water-shed in 500 days or about 16 months. He hence concludes that, as this rate of discharge is highly improbable, there must have been "a depression of the region to the extent of 100 or more feet"; the era in which it took place was that of greatest depression during the Champlain period, when the ice was most rapidly melting away. The Trenton gravels are referred to a later part of this period.

3. *Jura-Trias of Southwestern Colorado;* by R. C. Hills. (Communicated).—The Jura-Trias period of Southwestern Colorado is divided into three epochs, not always clearly defined but well marked on the Rio De Las Animas, about three miles above Animas City, also on the Rio Dolores about 19 miles below Rico. The rocks of the lower epoch are exposed on the Uncompahgre, San Miguel, Dolores, La Plata, Animas and Florida. They consist of dark brown sandstone and conglomerate and brick-red sandstone and shale resting comformably upon the purplish beds of the Permo-Carboniferous.

The strata aggregate about 1,000 feet in thickness and are seemingly destitute of fossils.

The rocks of the middle epoch, absent on the Uncompahgre, begin on Leopard Creek, a few miles north of its junction with the San Miguel, and reach a maximum thickness of 250 feet on the Animas. On the upper San Miguel the lower portion of the beds is generally red laminated sandstone. Elsewhere they consist of light green micaceous sandstone and gray and drab slaty and massive sandstones interstratified with calcareous conglomerate which predominates in the upper part of the beds.

It varies in texture from a typical conglomerate to a rock in which the pebbles are so small, well-rounded and compactly cemented as to suggest, at first glance, an oölite. It is characteristic of the middle series and generally contains fragments of bone and teeth of saurians.

In the light-colored sandstone indistinct leaf impressions are, in some places, quite numerous. Tracks of a diminutive species of saurian occur in this rock on the San Miguel; although the saurian remains seem to be confined to the bands of conglomerate. Eleven or twelve determinable species of plants, one species of Ganoid and one Gastropod have been obtained from this division.

The upper member of the formation consists of about 250 to 300 feet of brick-red sandstone, absent on the Uncompahgre and San Miguel. Thus far it has yielded only one species of plant.

The rock overlying the formation on, and south of, the Dolores

is a pinkish-colored cross-grained massive sandstone. It underlies the gray sandstone of the Dakota group and is briefly alluded to by Holmes.* On the Uncompahgre and on the San Miguel, near the mouth of Leopard Creek, the Jura-trias is overlaid by a laminated sandstone of like color, having a band of bituminous limestone about 7 feet thick at the base. On the North Fork of the San Miguel the sandstone is generally gray and the limestone is from 20 to 40 feet thick.

This group is slightly unconformable with the Jura-trias, but, contrary to my statement in a previous communication on the subject,† it is conformable with the Cretaceous and more likely to be Lower Dakota than Jurassic.

III. Botany and Zoology.

1. *Notes on Gramineæ;* by George Bentham, F.R.S. Extract Jour. Linnean Society, vol. xix, p. 14–134.—A modest title to a most important essay, in which this veteran botanist sets forth the general arrangement he has made of the genera of Grasses, to appear systematically and fully in the ensuing part of the Genera Plantarum. It is the result of a critical study of the whole order, with the aid of unequalled collections, and under the light of unexampled experience. We shall not attempt an analysis of that which is itself an analysis of an extensive work, nor touch upon the history of the taxonomy of the order, which Mr. Bentham succinctly sketches, nor upon his view of the homology of the floral organs and their adjuncts, which has been discussed in a separate paper a few years ago, of which due notice was taken in this Journal. Botanists do not need, and no others would be interested in, an abstract of these views and conclusions. In his reference to the morphology of the lodicules, Mr. Bentham hesitates whether to regard them as bractlets or as the representatives of perianth. His main objection to Hackel's conclusion—that they are bractlets—is their fore and aft position; but as this is a common position in the Monocotyledones, it seems rather to tell in favor of Hackel's view.

The arrangement of the genera makes some new associations and representations which may horrify old-fashioned agrostologists. In the two great divisions (which are those of R. Brown with a difference), and in the tribes (14 in number), much is made of articulation, which is of minor importance in most other orders. How the scheme will work remains to be seen. It is not probable that any living botanist could make a better one. The reader will probably be surprised to learn that, predominant as *Gramineæ* are in individuals, they are surpassed by the *Orchideæ* in the number of species. A. G.

2. *Flora Brasiliensis.*—The *Gramineæ* are continued by Doell in fasc. 83 (*Bambuseæ* and *Hordeaceæ*, the latter chiefly European species naturalized or cultivated in Brazil): fasc. 84, a large one, contains the greater part of the monospermous *Rubiaceæ* by Mül-

* Hayden's Report, 1875, page 266. † This Journal, vol. xix, 1880.

ler of Geneva. *Palicourea* and *Cephaelis* are reduced to *Psychotria*, of which there are 250 Brazilian species, although *Mapouria*, with 68 species, is kept distinct and made to include *Geophila*.

A. G.

3. *Diagnoses Plantarum novarum Asiaticarum:* IV. scripsit C. J. Maximowicz. Mel. Biol. Bull. Acad. Sci. St. Petersb. 1881. —It is pleasant to see more of the systematic work of Maximowicz, especially when it relates to Japan, as does some of it in the present fasciculus. *Hypericum pyramidatum* is identified with *H. Ascyron* and with the Japanese species; *H. Japonicum* of Japan, with *H. mutilum;* but it is remarked that the species in question can hardly be that of Linnæus, on account of a phrase in Mantissa, ii, 456. We certify that *it is* the Linnean plant, and also the Gronovian. And by tracing back the unfortunate addition in the Mantissa, made nearly twenty years later: "Folia tam arcte cauli appressa ut vix conspicua," it may be seen that Linnæus quoted Clayton's remark from a wrong species; and moreover that this is not *H. Sarothra*, for of it is said, "caule hirsuto." It is, indeed, *H. pilosum*, Walt. A synopsis is given of the E. Asian species of *Euonymus* and of *Celastrus*, and both are made feminine names, the former on the authority of Pliny, the latter on that of Theophrastus. A key is given to all the known species of *Chrysosplenium*, 39 in number; also of *Triosteum*, of which five are now known. *Lagotis* of Gærtner is taken up in place of *Gymnandra* of Pallas, and is said to be six years in priority. Two E. Asian species are added to *Kœnigia*, and the genus is brought very near to *Polygonum*. Our *Ostrya Virginica* is identified in Japan.

A. G.

4. *On the Power possessed by Leaves of placing themselves at Right-Angles to the direction of Incident Light;* by Francis Darwin. Journal of the Linn. Soc., no. 112 (vol. xviii, p. 420–455), published June, 1881, read Dec. 16, 1880.—Taking up this subject where it was left by his father and himself in the work on "The Power of Movement in Plants," Mr. Francis Darwin, in this paper, records his investigations and experiments made with a well-devised modification of Sachs' Klinostat, with the view of determining whether Frank's or DeVries's explanation of the position which leaves normally assume with respect to the light is the more tenable. While the vertical position assumed by the growing plant's axis is attributed to geotropism and heliotropism, Frank attributes the position taken by leaves (with one face to the sky and the other to the ground) to transverse geotropism and transverse heliotropism. "An organ which grows transverse-geotropically, places itself horizontally. . . . In the same way a transversely heliotropic organ has an inherent tendency to place itself at right-angles to, instead of parallel [as does the stem] to the direction of incident light. It may be said that this is no explanation at all; and this is true in a certain sense. But there is no reason why it should be more unsatisfactory than the accepted explanation of the vertical growth of stems and roots, namely, that they

have an inherent power of growing in these directions." Indeed the one is just as satisfactory or unsatisfactory as the other. The terms "geotropism," "heliotropism," "apheliotropism" and the like, transverse or otherwise,—now a numerous brood,—are useful and not misleading when held to mean only that, in fact, a leaf "has an inherent tendency to be horizontal" or "to place itself at right-angles to the direction of incident light" and "the hypocotyl of a seedling has an inherent tendency to grow vertically upwards." These technical terms are unsatisfactory when they are supposed to carry more explanation than the simple and untechnical statement does. But do leaves take their position in virtue of an inherent tendency? This is substantially denied by DeVries, or at least he maintains that the assumption is needless, for that it may be a result of an antagonism between positive and negative heliotropic and geotropic forces, or between these and what he calls *epinasty* and *hyponasty*. These new technical terms are simple in meaning. An organ, such as a leaf, is epinastic when the upper half grows in length more than the lower, and the effect is convexity above and concavity below, or downward curvature: it is hyponastic when the reverse takes place. And the suggestion is, that the horizontal position of a leaf under zenith illumination may be due simply to an equilibrium between two or more of these opposing forces. It is unnecessary to enter into particulars of how this obviously might produce the effect: for the result of Mr. Francis Darwin's experiments is a clear disproof of DeVries' suggestion. In the "fundamental experiment: . . if a plant whose leaves have the power of placing themselves at right-angles to incident light is growing normally in the open air and lighted from above, its leaves will be horizontal. Let the plant be now made to rotate on a klinostat [so slowly that no centrifugal effect will be produced, but rapidly enough to destroy all geotropic action] so that the axis of rotation coincides with the axis of the plant. And let the direction of the incident rays of light be parallel to the axis of rotation, so that the morphologically upper side of the leaves is illuminated by rays striking them at right-angles, just as they were when the plant grew on the ground. Then, if the normal horizontal position is the result of a balance between geotropism (positive or negative) and any other force—epinasty, hyponasty, positive or negative heliotropism,—it is clear that, geotropism being destroyed by the rotation, the balance cannot be maintained." The experiments, varied in many ways, and with arrangements to eliminate epinastic and hyponastic tendencies, plainly bring out the conclusion "that the power which leaves have of placing themselves at right-angles to the incident light is due to a specialized sensitiveness to light, which is able to regulate or govern the action of other external forces, such as gravitation, or of internal forces, such as epinasty." A. G.

5. *The Botanical Collector's Handbook.* By W. WHITMAN BAILEY, Olney Professor of Nat. Hist. (Botany) in Brown University, R. I. Salem: Bates, 1881. pp. 139, 12mo.—This is

No. III of The Naturalist's Handy Series, and handy it is. It patiently and particularly imparts to the incipient botanist the information which he needs, and which he will not find much of in his text-books and manuals,—how to herborize, with full particulars and, indeed, figures, of all the implements he can possibly require; how to prepare his specimens for the herbarium, and to arrange and manage the same; what books are most needed; what and where the principal public herbaria of the United States are (the Philadelphia herbaria omitted!); and there are special chapters on the management of the Cryptogamia, in which the author has been much assisted by specialists. The veteran collector, Charles Wright, contributes the article on the preparation of *Cactaceæ*, and much else in the way of herborization is from his large experience. The book appears to supply a recognized and increasing want. A. G.

6. *The Greenland Flora.*—A year hence the classical *Flora Danica* will be terminated by the completion of the seventeenth volume. The work will contain figures of 4,000 species of plants, of Scandinavia, including Greenland and Iceland. It has been published wholly at the expense of the King of Denmark, and is a right royal work indeed. At its completion the plates (in folio) which relate to Greenland plants, and which illustrate its whole flora, are to be separately issued, with a brief letter-press, under the title of *Icones Floræ Groenlandicæ*. As this flora is in one sense American, and as the copies of the whole Flora Danica in the United States are and must be very few, we take pleasure in announcing this illustrated Greenland Flora to American botanists. Some of them will wish to possess it. The price of uncolored copies is fixed at 56 francs, of the colored at 236 francs. It should be added that, as the impression is strictly limited, application should be made very promptly. The editor, Professor Joh. Lange, Copenhagen, informs us that he will himself receive subscriptions, up to the first of May next. A. G.

7. *A Memoir on the Echinodermata of the Arctic Sea to the west of Greenland;* by P. Martin Duncan and W. Percy Sladen. Large 4to, 82 pp., six lithographic plates. London, John Van Voorst, 1881.—This work is of special importance to American naturalists interested in this group of animals, for a large proportion of the species treated are found upon the New England coast. All the species are described in detail and nearly all of them are well illustrated. The whole number of species is thirty. Seven are holothurians;* of these all, except, perhaps, *Orcula Barthii*, are New England species, and the latter occurs on George's Bank and off Nova Scotia. Eight of the ten starfishes occur on the New England coast, the ninth (*Asteracanthion* [*Asterias*] *polare*) occurs in the Gulf of St. Lawrence and off Nova Scotia, and only one is, so far as known, peculiar to the

* The authors have included, erroneously, I believe, as the young of *Cucumaria frondosa*, the form that is regarded by me, and many others, as a distinct species (*Pentacta minuta*).

Greenland seas (*Pedicellaster palæocrystallus* Sladen); but it is possible that a *Pedicellaster* dredged in the Gulf of St. Lawrence several years ago, by Mr. Whiteaves, who sent me a specimen, in poor condition, for examination, is identical. Of the nine ophiurans, including *Astrophyton Agassizii*, five are common New England species; *Ophioglypha Stimpsonii* occurs on the Grand Banks and in the Gulf of St. Lawrence (Whiteaves); *Amphiura Holbœlli* occurs in the Gulf of St. Lawrence; while *Ophiocten sericeum* (Forbes) and *Ophiopleura arctica* Duncan appear to be confined to the arctic waters. The latter is, however, closely related to *Ophioglypha* (*Ophiopleura*) *aurantiaca* V.,* described in the last number of this Journal, which has been taken by us, several times, off the south coast of New England. This genus, therefore, can no longer be regarded as peculiar to the arctic region. Of the three crinoids one (*Antedon Eschrichtii*) is recognized as inhabiting the New England region, for it is common on the Banks off Nova Scotia, and especially off Cape Sable, N. S.; *A. celtica* Norm. and *A. prolixa* Sladen are not known from our coast, unless the latter be the same as some of the forms that I have hitherto called *A. Sarsii*, our commonest species, which it certainly closely resembles, in some respects.

In discussing the geographical distribution of the species the authors recognize the large number of species that extend southward along the North American coast to Nova Scotia, Maine, etc., but in a number of cases the range on our coast, as determined by our later researches, is more southern than they give. Thus, *Cucumaria* [*Pentacta*] *frondosa*, *Psolus* [*Lophothuria*] *Fabricii*, *Ctenodiscus corniculatus* [=*crispatus*], *Ophiacantha spinulosa*, *Astrophyton Agassizii* have all occurred south of Cape Cod; while *Stichaster albulus*, *Cribrella oculata*, *Ophioglypha Sarsii*, *Ophiopholis bellis* [=*aculeata*] are common as far south, at least, as the region off Chesapeake Bay, and very likely will be found to go much farther south, along the Atlantic slope, in moderate depths. Finally, we may add that at least 25 of the 30 species (or about 83 per cent) extend as far south as the Gulf of St. Lawrence and Nova Scotia; 22 extend to the Gulf of Maine; 11 pass to the south of Cape Cod; 5 extend to the region off Chesapeake Bay. A. E. V.

8. *Discovery of a rare fresh-water shell* (*Gundlachia*) *in western New York;* by JOHN M. COOKE.—In the summer of 1880 I found several individuals of this genus in the waters of a "Sucker Brook," which flows through the village of Canandaigua, N. Y. The species does not agree either with *G. Californica*, nor *G. Meekiana*, our two American species. Four have been described by Pfeiffer and Bourguignat from the West Indies. The specimens which I found were in a pool formed in the summer shrinkage of the stream. In the last season I was unable to find them

* This species was described (p. 141) as an *Ophioglypha*, but it is evidently congeneric with *Ophiopleura arctica*, from which it differs in the smaller size of the under arm-plates, upper arm-spines larger and flattened, differently shaped mouth-shields, etc.

again. They were associated with *Ancylus* and other common forms, and it is in the hope of finding them in the future, in sufficient quantity to enable me to make a study of the animal and its life history, that I d fer any description of the shell, incomplete as it would necessarily be.

In examining a Quaternary fresh-water shell-marl from St. Helena Island, off the coast of South Carolina, I have found a *Gundlachia* among the other shells — *Ancylus*, *Planorbis*, *Succinea*, *Pisidium*, etc., but always too immature to be identified with any species existing either on the Continent or in the West Indies. This is Mr. Tryon's opinion, as well as this, that the species of the associated genera mentioned are several of them both West Indian and Continental.

It is interesting, therefore, to find along with the *Gundlachia*, a species (*Pupa* (*Vertigo*) *hexadon*) described by C. B. Adams from Jamaica, and not as yet identified on the Continent. It was in this shell-marl that almost the entire skeleton of a *Mastodon* was found, about fifteen years ago, by Capt. C. S. Boutelle, of the U. S. Coast Survey. J. M. C.

IV. Miscellaneous Scientific Intelligence.

1. *Minor Planets.*—Since the list of minor planets in volume xviii was published, there have been added *thirteen* to the number.

210	Isabella,	discovered by	Palisa,	Nov. 12, 1879
211	Isolda,	"	Palisa,	Dec. 11, 1879
212	-------	"	Palisa,	Feb. 6, 1880
213	Lilæa,	"	Peters,	Feb. 17, 1880
214	Aschera,	"	Palisa,	Mar. 1, 1880
215	Oenone,	"	Knorre,	Apr. 7, 1880
216	-------	"	Palisa,	Apr. 10, 1880
217	-------	"	Coggia,	Aug. 30, 1880
218	-------	"	Palisa,	Sept. 4, 1880
219	-------	"	Palisa,	Sept. 30, 1880
220	-------	"	Palisa,	Feb. 23, 1881
221	-------	"	Palisa,	Jan. 18, 1882
222	-------	"	Palisa,	Feb. 9, 1882

The following names have been given to planets previously discovered: (204) *Kallisto;* (205) *Martha;* (207) *Hedda;* (208) *Lacrimosa.* H. A. N.

2. *Hailstorms.* — A letter to the editors from Mr. J. A. B. Oliver (Athenæum, Glasgow, Scotland), states that he is preparing a memoir for the Meteorological Society on "Hailstorms." He asks any persons, who have opportunities of observing hailstorms, to furnish him with particulars of them. The points to be particularly observed are as follows:

1. *Date*, and hour of the day. 2. *Area of the storm*, if it assume the tornado form, give (*a*) length of the course, (*b*) breadth. (*c*) direction of motion, (*d*) rate of progression. 3. *Physical features* of the locality, (*a*) elevation, (*b*) mountains and plateaus, (*c*) rivers and valleys, (*d*) forests, &c. 4. *Temperature*, (*a*) before the storm, (*b*) after the storm, and if possible to be observed, (*c*) changes during the storm. 5. *Barometrical readings* frequently taken during time of hailstorms. 6. *Wind*, (*a*) direction near the earth's surface, (*b*) direction in the higher regions

as indicated by the cloud motion, (c) force. 7. *Preceded or followed by rain.* 8. *Aspect of the clouds.* Note if there be any appearance of two separate strata at different elevations. 9. *Electrical phenomena*, should there be lightning, note the relation between the discharges and the fall of the hail—whether the lightning precede the hail, or *vice versa*. 10. *Duration* of the storm at one spot. 11. *Sound.* Note if a peculiar noise precede the descent of the hail. 12. *Conformation and size of the* [illegible] Weather before and after the storm.

3. *Schott's Tables and [illegible]ts of the Precipitation in Rain and Snow in the United States and some adjacent parts of North and South America*, published by the Smithsonian Institution. A new edition (second) of this very valuable memoir was issued in May last by the Smithsonian Institution under the direction of Mr. C. A. Schott. It makes now a quarto volume of 248 pages, with 10 plates. In the first edition the records were tabulated down to the close of 1866; in the new, to the end of 1874, and to some extent to the end of 1876. The five rain charts of this edition were constructed between April and June, 1880, and are made of the same size as the temperature charts of the Smithsonian Memoirs by Schott. The explanatory notes and deductions have been written anew, and various other changes have been introduced.

4. *Boston City Water: Report on a peculiar condition of the Water in November*, 1881; by Prof. IRA REMSEN, with notes by A. HYATT and W. G. FARLOW.—The "peculiar condition" is one observed in the waters supplied to cities at certain seasons, in which the taste is a "cucumber taste" or a "fish-oil" taste. Prof. Remsen found in his observations that such waters contained more "albuminoid ammonia" than those not having the taste, and by this observation ascertained the particular ponds that sent to Boston the offensive waters. He afterward examined the mud of the bottom of Farm Pond, without positive results; detected green masses of the size of pin-heads, which rose to the surface, and were recognized as plants of the *Nostoc* family by Prof. W. G. Farlow, but which did not have the smell; obtained from the screens, through which the water passes at the effluent of the gate-house of the pond, among dead leaves, etc. "some curious masses, green to brown in color," which gave off the disagreeable "cucumber odor," much intensified; some of the pieces, 4 or 5 inches in length, though most not over an inch, and so reached the root of the matter. Prof. Farlow recognized the material as a fresh-water sponge, and Prof. Alpheus Hyatt as the common species *Spongilla fluviatilis*.

5. *The Lalande Astronomical Prize* was awarded by the Academy of Sciences of Paris, at its recent annual meeting, to Professor Swift, of Rochester, N. Y.

6. *La Lumière Électrique.*—This excellent electrical journal, since the beginning of the year, appears but once instead of twice weekly; at the same time the size of the numbers has been increased from 32 to 48 columns.

7. *Cosmos-Les-Mondes.*—With the beginning of 1882 the well-known review, edited by the Abbé Moigno, commences volume I of a *third series*.

RHAMPHORH

HESPERORNIS PHYLLURUS, Marsh ½.

RHAMPHORHYNCHUS PHYLLURUS, Marsh.